The subtopics in sections 8.6 through 8.14 are from the National Institute of Standards and Technology (NIST). Approximately 30 awards will be made on these subtopics.

8.6 NIST TOPIC: QUALITY ASSURANCE

8.6.1T/A SUBTOPIC: Quality Management and Health Care

In recent years, health care costs have been 13 percent of the United States Gross Domestic Product and rising. Quality improvement principles are being used increasingly to improve productivity and efficiency of health care delivery and to help contain costs.

The Malcolm Baldrige National Quality Award Health Care Pilot Criteria have the potential to offer assistance to those providing U.S. health care. Proposals are sought on definition of criteria for determination of health care outcomes and adjustments of health care outcomes data to account for case mix and patient risk. The development of algorithms for determining such data and statistical techniques for analysis of the data are sought. Collaborative research with health care institutions is encouraged to provide data for assessment of algorithms.

8.6.2T SUBTOPIC: Quality Management and Education

There is a growing movement to apply quality management principles and the Malcolm Baldrige National Quality Award Education Pilot Criteria to educational systems throughout the United States. Included in this movement are K-12, as well as higher education.

Proposals are sought in the area of outcomes measurements to be used in determining appropriate indicators and improvement trends in educational outcomes. Collaborative research with schools or school districts are of particular interest, since it permits evaluation of research results.

8.6.3T SUBTOPIC: Quality Management Self-Assessment Software

Many businesses and organizations are using Baldrige-based criteria for self-assessment. Self-assessment is frequently used in a strategic planning process by which businesses/organizations deliver greater customer value while improving productivity and asset allocation.

Proposals are sought for a group-ware, LAN-based software package that enables organizations to conduct self-assessments based on the following three sets of criteria: (1) the Malcolm Baldrige National Quality Award Criteria; (2) the Education Pilot Criteria (or Award Criteria); and (3) the Health Care Pilot Criteria (or Award Criteria).

The package shall incorporate the latest version of each of the three sets of criteria for purposes of on-line reference. Users need to be able to record, edit, print, collaborate, compare, and summarize comments and scores for all criteria Categories/Items/Areas to Address. Documentation shall be sufficient to enable novice users to employ the software. Desirable attributes are a fully-integrated graphical interface, a general word-processing capability, and an on-line help system.

8.7 NIST TOPIC: ADVANCED TECHNOLOGY PROGRAM

8.7.1T SUBTOPIC: Technologies for Large Area Electronic Materials and Devices

There is growing technological and commercial interest in active thin film materials, coatings, and membranes for large area electronic applications. These include thin film amorphous silicon, which finds use in flat panel displays and in photovoltaic power modules; solid polymer and ceramic ion conductor membranes, employed in fuel cells and laminated lithium polymer batteries; and electrochromic coatings for smart windows. In all of these applications control of materials properties and structures at the nano or micron level in the solid state is important and results in new electronic functionality over areas larger than a silicon wafer.

To be viable in the commercial marketplace, these thin large area, multilayer devices have to exhibit high performance to size or weight ratio and be capable of being made by processes amenable to cost-effective manufacturing. Proposals are solicited that target the development of new materials, processing, or device structures that can result in significant large area device performance improvements or lead to lower manufacturing cost. Especially encouraged are proposals that are aimed at the development of new rapid, high volume fabrication, or that innovatively adapt processing proven in one industry to large area electronic applications. Emphasis should be directed at large area electronic multilayer devices, especially those that are enabling for power generation and energy storage for wireless, mobile broadband telecommunications. Specifically excluded are proposals in the microelectronics area.

8.7.2T SUBTOPIC: Learning Technologies

Learning technologies relate to an interest in technical solutions which enhance the delivery of information to learners and educators, as well as directly enabling learner-centered activities. Although the requirements of learners and educators vary from one setting to another, certain processes fundamental to learning and pedagogy can be

greatly enhanced by information technology. These include, but are not limited to: a) knowledge representation -- making educational tools which are usable and comprehensible; (b) knowledge management -- facilitating the acquisition, organization, and dissemination of information; (c) interaction facilitation -- making objects in an on-line learning context manipulable and supporting sense-making activities; and (d) learning contextualization -- maintaining learning contexts and enabling a set of information to become a common object of consideration within a learning community.

Technical challenges associated with supporting these processes and for which proposals will be accepted are:

1. Content production and management software. Here the main technical challenges relate to the following fields: (a) search algorithms; (b) multimedia and cross-media indexing tools; and (c) learner-centered and learner-paced navigators. Probabalistic graphical models would be included here as applicable to database mining and navigation.

2. Visualization software as applicable to the user interface. Here the main technical challenges appear to fall within the following areas: (a) 3D optimized displays, (b) visual user preference filters, and (c) interactive visualization software.

3. Distributed simulation as applicable to networked open systems. Here the main technical challenges appear to fall within the following areas: (a) network simulation; (b) artificial intelligence monitoring software; and (c) collective and iterative user support technologies (i.e., authoring tools).

4. Systems management. Here the main challenges fall into three areas: (a) usability testing and design, (b) pricing and delivery, and (c) capacity management.

It is believed that the successful development of technical solutions in any of these domains will depend on the clarity of pedagogical objectives and a depth of understanding of the institutional context within which the envisioned learning technologies will be deployed.

8.7.3T SUBTOPIC: Emerging Thin Materials and Devices

Novel thin film materials, coatings, and membranes are used in a unique multilayer structure where control of materials properties, structures, and phases on a nano or micron level is important; surface and interface molecular engineering is paramount; novel morphologies are often employed, such as amorphous or nanocrystaline phases;

new functionality is achieved in the solid state over large areas; and high performance is required that pushes optoelectronic or mechanical strength limits.

Thin film, coatings type processing is employed, which makes possible large area coverage; low cost; high volume, rapid throughput; and automated, continuous manufacture.

Novel device or parts structures are possible in which integrated architectures can be employed; monolithic arrays of many devices can be possible with relatively small feature sizes; large areas are covered but with low materials usage; high performance to size or weight ratio is possible; properties of the underlying substrate is enhanced; and multidimensional combinations of many thin film materials are employed. Emphasis is placed on achieving new functionality in applications as diverse as smart electrochromic windows and thin film batteries; high resolution displays using new carbon field emitters; large area, thin film amorphous silicon semiconductors for digital X-ray imaging; and superhard diamond and amorphous carbon coatings for cutting tool and tribological applications; multilayer, ion conducting, electronic ceramic membranes for oxygen and power generation; and rapid thermal processing which enables large area semiconductor processing important to photovoltaic and semiconductor devices.

8.8 NIST TOPIC: ELECTRONICS AND ELECTRICAL ENGINEERING

8.8.1T/A SUBTOPIC: Characterization Techniques for Silicon on Insulator Material

Silicon on Insulator (SOI) is an emerging technology of choice for use in production of silicon integrated circuits. Two approaches have been developed for producing the material: ion implantation of oxygen and bonding and etching of silicon wafers. Both approaches have succeeded in reducing the levels of microscopic defects in the silicon and oxide films to low, but detectable, levels. Extremely sensitive characterization techniques have been developed to achieve this result. As the defect level of the material is reduced, and the production level of wafers increased, present characterization requires improvement. In general, the measurement challenge is to ensure very low levels of microscopic defects in heavily processed thin film structures.

NIST is seeking proposals to develop characterization tools to address the specific problems of SOI technology. Possible topics include: (1) higher sensitivity techniques for microscopic detection of defects, (2) nondestructive techniques for characterization of large area (200 mm) SOI wafers, (3) new techniques for detection of new defect

types, (4) quality control characterization methods suitable for use during the SOI wafer fabrication process, and (5) automation of characterization for volume production of SOI.

The Phase 1 contract will be a proof-of-principal demonstration. Proposals should include procurement or production of sufficient suitable material (SOI wafers) for development and demonstration.

8.8.2T SUBTOPIC: Data Exchange Tools for Electronics Assembly

Process control files provide the instruction sets used by electronic assembly equipment to accomplish specific tasks. The lack of a standard for the construction of process control files has resulted in a proliferation of proprietary, vendor specific systems, which has proven to be a burden to their customers. It is believed that significant cost savings and greater flexibility could be realized by software developers, equipment suppliers, and electronics manufactures through a standardized method to represent product and process data in process control files. Such a standard is being developed (the Standard Recipe File Format) that addresses this technological gap.

Once the SRFF standard has been established (a stable version is expected in 1997), the need for certain low-cost generic software tools would arise almost immediately in the electronics manufacturing industry. Companies will either develop SRFF-compliant tools internally, or purchase them. Since tools outlined in this effort would be pre-competitive in nature, developing these tools internally would not be a revenue generator for most companies—but a cost. Consequently, establishing a market source for these tools would therefore save companies valuable resources, both in terms of tool development and equipment support. The development would be conducted once, versus dozens or hundreds of times.

NIST is soliciting proposals for an initial set of SRFF-compliant tools. The contractor would work in collaboration with the Surface Mount Equipment Manufacturers Association's SRFF development effort to both define, prototype, and finally make commercial-ready a suite of SRFF-compliant tools. Such a tool suite would be expected to include: a SRFF parser; tools to load SRFF files into a database, and then manipulate and visualize the data; and tools to handle user-extensions to SRFF files. Once available, these tools would be used by NIST researchers to demonstrate electronic commerce of electronics assembly services, and would complement the work NIST is doing with the National Electronics Manufacturing Initiative. More importantly these tools would have a positive impact on the U.S. Electronics manufacturing industry: this impact could easily be measured through the number of tools sold by the winner of this SBIR.

8.8.3T SUBTOPIC: Virtual Electronic Component Toolbox for ECCI

Electronic Commerce of Component Information (ECCI) requires the ability to locate, organize, and access component information such as, simulation models, physical dimensions, thermal data, timing models, synthesis scripts, and other types of engineering data. This is becoming an increasingly complex task. The current ability to "publish" such information electronically is making this task more challenging, due to the need to "link" or wrap these diverse sources of information so that a design engineer can make effective use of them. Tools are needed to help electronics designers and manufacturers locate, organize, access, and edit the information and data for electronic components. A designer may know that they need an electronic component which satisfies a set of performance and functional parameters. There are currently no tools available to help locate, organize, edit, and access such information via the WWW so that it can be efficiently incorporated into a design and manufacturing lifecycle.

NIST is soliciting proposals for the development of a such a tool or suite of tools, to be designed in a phased approach with the initial implementation being a Java applet (for platform independence), which can display and edit component information as defined by the ECIX Pinnacles Component Information Standard (PCIS) format, including links to online dictionaries, such as the NIST developed dictionary framework. This tool would be very extensible and would allow the engineer to dynamically add links to any additional component information which may exist both internally and externally to his company. The long term goal is to develop a tool that could be made commercially available at a very affordable price, to allow designers and manufacturers to organize and access component information within an electronic commerce infrastructure. This could also be thought of as an electronic toolbox where engineers can collect a wide variety of electronic information about all the components they use in their designs.

Future phases of this proposal would add the ability to browse, link, edit, maintain, and publish other standard formats as they emerge within the industry. Future development would also allow manufacturers to easily publish and maintain their electronic databooks via a Java applet capable of reading and writing standard formats, such as Pinnacles ECIX, and other emerging standards including Virtual Socket Interface Alliance (VSIA) developed standards. Version control, preferred parts lists, and intelligent BOMs (Bill of Materials) would also be part of this future work. Another important aspect of future work will be the inclusion of intelligent agents customized to

search for new engineering data as it comes on-line, and to link that data into the existing collection of data.

8.8.4T SUBTOPIC: IT Metrics for Electronics Manufacturers

While automation technology promises and often delivers tremendous benefit to manufacturers, automation choices are often made without the benefit of reliable business metrics. Managers require effective metrics to allow them to make effective comparisons among factory information system options, such as the selection of Enterprise Resource Planning or Manufacturing Execution System software systems, or deciding to upgrade legacy systems in-house. One role of business metrics would be to demonstrate that the promised value is indeed delivered. This proof is complicated by the fact that there will also be other active projects that impact the same metrics, such as product design improvements to improve yield, which would need to be accounted for. Another objective for business metrics would be the ability to project the cost of NOT performing an installation or upgrade. This should include an assessment of the costs incurred in sneaker-net, data reentry, data duplications, and other costs associated with un-integrated implementations in place.

NIST is soliciting proposals to develop a set of business metrics that correlate technical metrics (such as MIPS, FLOPS, and data rates) with business metrics (such as factory effectiveness and time-to-yield) to aid manufacturing management in their efforts to build an optimum information infrastructure for deployment by electronics manufacturers. The contractor will work closely with the Factory Information Systems (FIS) Technical Implementation Group (TIG) of the National Electronics Manufacturing Initiative (NEMI) to develop such a set of metrics for electronics manufacturers. The project will result in a list of metrics that can be selected for use in evaluating FIS cost/benefit/risk in an electronic manufacturing environment. The metrics will be supplied as part of a report detailing each metric, its derivation from a common business metric, and how it is related to a FIS metric. The final deliverable is a procedure for applying and interpreting the metrics. This may be in the form of a spreadsheet or other automated software tool. The tool should support decisions ranging from NOT implementing any changes, to various levels of upgrades, to a fully integrated FIS integrating the full functions of the company. Verification against existing installations will be required to validate the accuracy of the metrics.

Schedule:

Phase 1 should include the following tasks: (1) survey metrics used in other (manufacturing and non-manufacturing) industries; (2) draft selected business metrics; (3) draft list of FIS metrics; (4) draft algorithm for correlation between business and technical FIS metrics; (5) final reports of above.

Phase 2 should include the following tasks: (1) a commercial-ready decision-support tool which implements the metrics, and is geared towards the electronics industry; (2) verification benchmark demonstration at one or more electronics manufacturing sites; (3) draft report of application of benchmark and verification against expected outcome; and (4) final reports and procedures.

8.8.5T SUBTOPIC: Scanning Probe AC Impedance Microscope

Dopant profiling of silicon in two-dimensions (2-D) with 10 nm spatial resolution and 10% accuracy over the dopant range of 10^{20} to 10^{17} cm^{-3} is a critical measurement need for next-generation integrated circuits. Two scanning probe microscope (SPM) methods have been developed to measure 2-D dopant profiles: nano-spreading resistance and the scanning capacitance microscope (SCM). Both techniques measure some aspect of the probe tip to semiconductor electrical impedance. Nano-spreading resistance measures dc resistance, while SCM measures capacitance with a resonant peak shift sensor at 915 MHZ. The impedance of the SPM tip to a semiconductor has not been extensively investigated at intermediate frequencies.

NIST is seeking proposals to develop instruments which will integrate analysis of the tip-to-semiconductor impedance from *dc to the low GHz* range with a scanning probe microscope. Desirable tools would be sensitive to variations in semiconductor dopant concentration, lifetime, surface states, dielectric constant, and/or buried layers of a multi-layer integrated circuit structure. Possible implementations of the tool may be an ac version of nano-spreading resistance with relaxed tip/sample constraints, or an ac impedance microscope capable of simultaneously measuring both the resistive and capacitive (real and imaginary) components of tip-to-sample impedance.

The Phase 1 contract will require an investigation of the tip-to-sample impedance over the frequency range of interest, techniques to apply high frequency signals to a semiconductor with a nano-probe tip (such as micro-strip lines), and identification of optimum frequency range and measurements for imaging the various properties of a semiconductor.

8.8.6T SUBTOPIC: Agile Wavelength Tuning for Diode Lasers

NIST has developed probes which use optical-fiber links and electro-optic transducers to measure rf and microwave electromagnetic fields. Such probes require a means for stabilizing their output against other environmental changes, such as temperature

changes and acoustic vibrations. One way to accomplish this could be by rapidly tuning the wavelength of the diode source laser over a 1 to 2 nm wavelength range in a few microseconds. Presently available tunable diode laser systems are unable to meet this demand.

NIST is soliciting proposals to develop diode lasers and/or tuning systems that will meet this requirement. A couple of possible technologies for realizing an appropriate tuning system might be electro-optics or surface acoustic waves, but any technology which meets the requirements would be considered. The system should simultaneously produce a narrow spectral line with a width of less than 10 MHZ and the capability of eventually getting below 1 MHz. Since such a tuning system would have applications in many other optical fiber based sensor systems, there would be a substantial commercial market. In addition, with only slight improvements, it could be used in wavelength multiplexed telecommunication systems, where a very large commercial market is expected to develop in the near future.

Reference:

Masterson, K.D., D.R. Novotny, and K.H. Cavcey. 1996. Standard antennas designed with electro-optic modulators and optical fiber linkage. Intense Microwave Pulses, IV, H. Brandt. ed. SPIE 2831, pp. 188-196.

8.8.7T SUBTOPIC: Electrooptic Modulator Wavelength Controlled Bias Point

NIST has developed probes which use optical-fiber links and electro-optic modulators to measure rf and microwave electromagnetic fields. Environmental effects such as temperature changes and acoustic vibrations cause changes in the modulator's optical bias points that affect system performance. As an alternative to trying to achieve complete stability in the modulator against such effects, NIST has pursued an approach whereby using an appropriate modulator design, such changes can be compensated by servo controlling the laser wavelength, thus achieving stability in the full system response.

NIST is soliciting proposals to develop electro-optic modulators specifically designed to meet this requirement. Techniques explored to date have utilized resonant cavities or unbalanced, two-beam modulators, and require additional discrete components, such as polarization spliters and Faraday rotators for proper operation. We would be interested in modulator designs that eliminate the need for such extra components, or which integrate them into a single structure. They should have complementary outputs to provide common mode noise rejection, and to use for feedback control of the laser

wavelength. Frequency response of at least 3 GHz is required, but a capability for extending it to above 20 GHz is also desirable.

Reference:

Masterson, K.D., D.R. Novotny, and K.H. Cavcey. 1996. Standard antennas designed with electro-optic modulators and optical fiber linkage. Intense Microwave Pulses, IV, H. Brandt. ed. SPIE 2831, pp. 188-196.

8.8.8T SUBTOPIC: 4-port On-wafer Calibration Software and Standards

This program will develop and commercialize calibration software, standards, measurement methods, and instrumentation for the on-wafer electrical characterization of microwave 4-ports. The aim of the system will be to reproduce, in a commercial environment, accurate multiport and multiconductor calibrations and measurements developed and under development at NIST. Both passive and electronic calibration standards may be considered. New test instrumentation may be developed or existing test instrumentation may be employed to meet these goals. The system should be designed for the accurate measurement of 4-port microwave components of the type being developed for wireless communications systems, and for package and interconnect characterization. The system design should allow eventual extension of the measurement technology to millimeter wave frequencies.

8.8.9T SUBTOPIC: *In Situ* Composition Measurements of Quaternary Semiconductors

A number of important optoelectronic devices are based on quaternary semiconductor alloy systems, for example, AlGaInP for visible lasers and InGaAsP for infrared optical fiber communication devices. The composition of the epitaxial layers in these devices is calibrated with separate growth runs and ex situ measurements, so that the current manufacturing process requires time and materials resources directed away from actual device runs, and cannot correct for run-to-run variations in real time. While optical techniques may be used to determine material band gap at growth temperature, this information is insufficient to determine a composition value for quaternaries, and deposited films can, therefore, reach an unacceptable level of strain before a problem is identified. We require a new technique or combination of techniques, including but not limited to, real time flux measurements and in situ optical spectroscopy, to determine compositions of quaternary III-V semiconductors during growth. Instruments should be designed or tested so as to identify and respond to the major causes of run-to-run variation in molecular beam epitaxy (MBE) and/or organometallic vapor

phase epitaxy (OMVPE) growth systems. This information may be used to reduce the cost of real-time measurement when one or more of the source material delivery subsystems are sufficiently reproducible to make flux monitoring unnecessary. Preference will be given to proposals in which Phase 2 work will include publication of measurement results and delivery of a prototype measurement system to NIST.

8.8.10T SUBTOPIC: *In situ* Resistivity Measurements during Epitaxial Growth of Semiconductors

Although a number of properties of epitaxial semiconductor films can be measured in situ, resistivity or doping level is still determined by post-growth characterization. The use of ex situ characterization mandates expensive calibration runs, limits flexibility in changing device design parameters, and generally requires destructive testing for samples with more than one layer. We are requesting proposals to demonstrate techniques for the measurement of carrier concentrations in the range of 1016 to 1019 cm-3 in semiconductor films as they are being grown. The techniques should be compatible with use in molecular beam epitaxy (MBE) and/or organometallic vapor phase epitaxy (OMVPE). In keeping with industrial needs for device manufacture, at least 20% accuracy and 10% precision should be achievable in principle. Phase 1 research should provide a proof-of-concept for the measurement technique and data analysis. Phase 2 work is expected to include demonstration of the measurement technique during growth of films, with different doping levels covering the above range.

8.8.11T SUBTOPIC: Cold On-Wafer Noise Source

Suitable artifacts are needed for use in interlaboratory comparisons of on-wafer noise-temperature measurements, and for use as industry check standards. Measurement of noise temperature is fundamental to general noise-parameter measurements. NIST is developing methods for the accurate on-wafer measurement of thermal noise to support measurements of noise parameters of integrated circuit devices, such as low-noise transistors. NIST has recently developed and verified the capability to accurately measure noise temperature on wafer, and is developing on-wafer noise sources with high noise temperatures (~10,000 K, ENR ~15 dB). There is now a need for a source with a low noise temperature, which is more sensitive to common error sources, such as ambient contributions to noise power.

The frequency range of interest is 1 GHz to 18 GHz, particularly the 8-12 GHz and 1-2 GHz bands, with a source noise temperature less than 150 K, and constant to within about 2 K over any 10 MHz frequency band. The source is intended for circulation in

inter-laboratory comparisons, and must be mechanically and electronically robust, with an output stable and repeatable to within 0.5%. The output lines should coincide with those of the NIST on-wafer CPW calibration set, and the reflection coefficient should be less than about 0.3. Electrical power or bias requirements must be satisfied by readily available power, voltage, or current supplies, and transferred to wafer by common CPW probes. Any additional required circuitry must be provided with the source. One possible source could be the reverse radiation from a FET. Approaches employing cold physical temperatures are discouraged, unless the need for cumbersome cooling equipment can be circumvented. A variable output noise temperature, although not required, is considered a desirable bonus, but only if source stability and repeatability are not degraded.

Such a cold noise source will have commercial applications beyond its intended use. It could be packaged as an internal reference source for systems measuring noise parameters, with accuracy improvements over systems using high-temperature sources. It could also be used to calibrate non-laboratory low noise temperature radiometers, as used in space applications.

References:

Randa, J. 1997. Noise temperature measurements on wafer. NIST Tech. Note 1390.

Williams, D., R. Marks, K. Phillips, and T. Miers. 1991. Progress toward MMIC on-wafer standards. *36th ARFTG Conference Digest*; Monterey, CA; 73-83.

Frater, R.H. and D.R. Williams. 1981. An active 'cold' noise source. IEEE Trans. Microwave Theory & Tech., MTT-29(4), 344-347.

Dunleavy, L.P. *et al.* 1997. Design and characterization of FET based cold/hot noise sources. *1997 IEEE MTT-S International Microwave Symposium Digest*, 1293-1296, Denver.

8.8.12T SUBTOPIC: Intrinsically Shunted Josephson Junctions for Programmable Voltage Standards

Superconductor-normal-superconductor (SNS) Josephson junctions are required for programmable voltage standard systems. SNS junctions can provide large critical currents (> 1mA) and I_cR_N products in the 10-100 microvolt range while maintaining nonhysteretic current-voltage characteristics. Significant advances have been made in low temperature superconductor (LTS) SNS junction technology using PdAu normal metal junction barriers. However, PdAu SNS junctions with 30 μV I_cR_N products have

critical current densities greater than 200,000 A/cm^2. This large current density is not ideal, because it requires junction diameters less than 2 μm. Since large currents are required to bias these very small junctions, the maximum ac or dc bias current that can be passed through wiring contacts and crossovers sometimes limits design performance.

NIST is soliciting proposals for the fabrication of LTS SNS trilayers with novel normal-metal barriers that provide resistivity greater than 50 $\mu\Omega$ cm. The superconducting material should be niobium. Junction barrier thicknesses should be adjusted in order to achieve current densities less than 100,000 A/cm^2 while maintaining I_cR_N products greater than 30 microvolts. Junction uniformity should be demonstrated by fabricating arrays of at least 1000 junctions. Arrays should be embedded in appropriate microwave circuits that ensure uniform microwave power coupling, so that power and junction uniformity can be characterized at the characteristic frequency of the junctions. Chip size and layout should be compatible with present NIST test probes for characterization at NIST.

8.8.13T SUBTOPIC: High Temperature Superconducting Programmable Voltage Standard

Josephson voltage standards working at 4^o K produce the ultimate in accuracy for dc voltage measurements at 10 V, and have recently been extended to rapidly programmable voltages up to 1 V. The requirement for operation at liquid He temperatures will limit the range of applications even for the more versatile programmable voltage standard. There have been significant recent improvements in the fabrication of high temperature superconducting (HTS) Josephson junctions. The possibility has arisen for a low-voltage high-speed measurement system using a HTS programmable array operating at temperatures between 30 K and 77^o K. NIST is soliciting proposals for the fabrication of a HTS Josephson junction array configured for binary programmable operation. The junction array and integrated microwave circuit should operate well above 30^o K using a junction technology capable of 1-s spreads less than +/- 10%. We require binary sequences of junctions with I_cR_N products of approximately 20-50 μV (and critical currents of at least 500 μA) at the operating temperature. Subarrays of at least 128 junctions are desirable for spread tests. The appropriate integrated microwave circuits will include coplanar waveguide transitions, termination resistors, and filters on the dc lines. Chip size and layout should be compatible with the present NIST test system.

8.9 NIST TOPIC: MANUFACTURING ENGINEERING

8.9.1T/A/CC SUBTOPIC: Computational Tools to Support Design Artifact Knowledge Repositories

Engineering design involves a mapping between one or more specified functions and a (description of a) realizable physical structure -- the design artifact. The design process involves both top-down decomposition and bottom-up problem solving. The development of computational tools to aid in the design process requires a rich object-based representation scheme that integrates knowledge-based reasoning, constraint processing, geometric modeling, and easy access to large component data/knowledge-bases. While the representation of geometric information has been the subject of extensive efforts, representations for other types of knowledge that are an essential part of the design process (such as function, behavior, and design rationale) are less mature and lack accepted standards. While the ultimate goal is to develop a general "intelligent computer-aided design tool," the scope of this proposal topic is limited to the development of a suitable scheme for both representation and access (index and retrieval) to part and assembly information, including design process models, multi-media data, and appropriate links to commercial CAD tools. An additional requirement is that the tool should be compatible with all platforms commonly used by small to medium enterprises, or should be easily accessible from such platforms (e.g., via the Internet).

NOTE: It is expected that a Phase 2 effort will result in the construction of prototypes.

8.9.2T/A SUBTOPIC: Software Components Specification and Performance Database

It is anticipated that a commerce in third-party software components will continue to emerge and flourish. Several key technologies and support structures must be developed in order to make this happen. One key hurdle is to allow potential users of software components to efficiently evaluate competing software components, based on the user's system design requirements. In the area of research algorithms for intelligent systems, a user has only a research paper or commented source code available to evaluate whether the software component will meet the system design requirements. At NIST, we have proposed a template of formalizable specifications that, when instantiated for a particular component, will completely define that component. (See http://isd.cme.nist.gov/proj/ sw_component_spec/formal.html to download a copy of a paper describing this work in more detail.) These specifications

can be employed by the user to efficiently and securely evaluate whether the component meets the system requirements.

We would like to see technologies and support structures to allow these specifications to be used to solve real applications of intelligent system software developers in U.S. companies. In particular, we would like to see a computer server be put in place that would be a repository for intelligent system software components specified according to the NIST model described above. A Phase 1 effort would be to design the database and its requirements. This would include: (1) design the database to allow the component developer to keep aspects of the component proprietary, while still allowing the user a variety of options to examine the nature and performance of the component; (2) design a user interface that will be required to enter components into the database easily and efficiently, in order to effectively entice developers to place their components in the database; and (3) design a user interface that will allow the user to effectively examine and even do early system simulations using the component specifications. A Phase 2 effort would be to create the server with its database, populate it with appropriate intelligent systems algorithms (components), and install it at NIST. An important requirement is that the awardees would need to perform this research in concert with researchers in the NIST Intelligent Systems Division (ISD).

8.9.3T/CC SUBTOPIC: Green Engineering Concepts for Next Generation Vehicles

Increasingly stringent environmental regulations are putting more and more pressure on the automotive industry to develop new concepts for component designs. As an example, at the turn of the century, most refrigeration systems were carbon dioxide-based. They were eventually replaced by more compact freon based systems. Because carbon dioxide costs 1/100th the cost of a non-ozone- depleting freon, and does not require the use of costly freon machinery, there is renewed interest in the use of carbon dioxide as a refrigerant for automobile air conditioning systems. This and other examples of environment-driven design concepts, are pushing researchers and developers to make these concepts realizable, practical, and affordable. The issue common to all these cases is the engineering design. Proposals are solicited that will utilize advanced CAD tools (such as network-centric CAD, and novel design exploratory tools) for the development of designs that will not only be simple, but easy to manufacture, taking into consideration multiple lifecycle aspects of the product.

NOTE: It is expected that a Phase 2 effort will result in the construction of prototypes.

8.9.4T SUBTOPIC: Telemetry System for Machining Applications

The purpose of this request is to develop a telemetry system, such that the basic data and new theoretical models required to optimize and increase productivity in high-speed milling can be optimized. The focus of the NIST research is on developing means for increasing tool vibrational stability, and on eliminating the need for empirical determination of process stability on a case by case basis. Vibrational stability is one of the major factors limiting material removal rates in high-speed milling. This is especially true in cases where significant tool flexibility is unavoidable, such as in the milling of deep channels or pockets with small corner radii. Consequently, a great deal of research has been devoted to both predicting the critical parameter values for the onset of vibrations (chatter), and to increasing the stability of the process.

In order to control tool vibrations in milling, improved measurement techniques are necessary. Specifically, a method must be devised to measure the deflections of rotating tools during machining, and preferably these deflections should be measured in the rotating frame of reference. One means of doing this is to take advantage of strain measurement techniques, such as those developed for measuring vibrations in turbines. These measurement systems make use of FM telemetry and inductively coupled power coils to operate and extract data from low mass strain gage-bridge-amplifier circuits mounted on the rotating equipment. In this effort, we are asking for the development of a telemetry system to measure dynamic strains in high length-to-diameter ratio tools during milling, such that NIST can use this information to devise new means of stabilizing tool vibrations and thereby increasing material removal rates. The proposed system will measure two bending strain signals with a bandwidth of 50 kHz per channel, with a measurement error of less than 1%. The system must operate at rotational speeds of up to 20,000 rpm, and fit in a tool holder on a high-speed milling machine. Detailed drawings of the tool holder are available from NIST. NIST also requires that in the future, similar systems be adapted to utilize other sensors, such as tool-mounted thermocouples.

8.9.5T SUBTOPIC: Virtual Manufacturing Metrology

Economically competitive manufacturing requires the efficient use of computer-controlled machine tools and coordinate measuring machines. Effective use of these capital resources involves selection of the machine best able to complete the job, i.e. neither over allocation nor under allocation of manufacturing resources. A principal determinant of quality in the manufacturing of discrete-part products is the ability to manufacture and verify the conformity of machined part features. One concept to accomplish this is the use of virtual manufacturing metrology, which is a computer simulation-based mathematical model of the capability and error sources of the machines. Typically this may involve many hundreds of simulations of the

manufacturing scenario; each simulation differing by the particular configuration of errors and uncertainties assumed to be present in the system. The resulting collection of simulations can be used to assess the conformity of the final result. This will be consistent with current ISO guidelines for the expression of measurement uncertainty.

The simulation should be capable of modeling real industrial conditions, including (but not limited to) environmental factors, operator effects, and the myriad of errors present in manufacturing and measuring equipment. The simulation should be based on data that is practically and economically obtainable in an actual factory environment, and the simulation integration between the machine tool and measuring machine should be seamless. The system should be capable of operating on standard Win 95/NT type computer platforms.

8.9.6T SUBTOPIC: Internet-based Manufacturing

U.S. manufacturers face unprecedented challenges and opportunities in the operation of information-based enterprises. The manufacturing industry is increasingly operating on a model of production in which Original Equipment Manufacturer's (OEM's) assemble products out of components produced by a network of widely distributed suppliers. This model is emerging into one in which manufacturing operations are treated as distributed services accessible via the Internet. The use of the Internet by OEMs to locate, contract, link, and even execute manufacturing services offers improvements in cost, cycle-time, and quality. The current opportunity is afforded by advances in several areas: (1) industry and government researchers are defining the Next Generation Internet to enable secure, dedicated bandwidth to its users, (2) electronic commerce protocols are emerging rapidly and through increasing use are becoming more effective, (3) standards are emerging for distributed object-oriented software systems that describe interfaces to manufacturing objects, and (4) Manufacturing Execution Systems (MES) are emerging that enable flexible control over manufacturing operations.

We solicit proposals to develop tools and protocols which address part or all of the following:

- Define manufacturing operations as network-based services.
- Link distributed manufacturing execution system frameworks into an extended manufacturing enterprise.
- Schedule and execute operations across a framework of distributed Manufacturing Execution Systems.

- Combine Electronic Commerce protocols with distributed object protocols to publish, subscribe, and contract for manufacturing services.
- Formalize information needed to interface distributed manufacturing services.
- Combine precise descriptions of manufacturing processes and operations with enabling protocols and methodologies to enable global distributed commercial operations.
- Apply advances in distributed object technology, advanced process control and simulation to establish a new network-based manufacturing paradigm.
- Provide proof-of-concept demonstrations to reduce risk of adopting the paradigm of distributed, Internet-based manufacturing services.
- Provide metrics for intercomparison and adoption of technologies enabling Internet-based manufacturing services.

It is recommended that proposed efforts leverage existing work in the research community on electronic commerce, distributed object systems, Manufacturing Execution Systems, and enterprise integration. Web sites for material referenced above include: (1) NIST Manufacturing Engineering Laboratory, Manufacturing Systems Integration Division: www.nist.gov/msid, (2) CommerceNet: www.commerce.net, (3) Object Management Group: www.omg.org, (4) National Industrial Information Infrastructure Protocols: www.niiip.org. (5) SEMATECH CIM Application Framework: www.sematech.org/public/cim-framework/home.htm.

8.9.7T SUBTOPIC: Next Generation Process Exchange Tools and Applications

As manufacturing companies move toward increased integration, there is a growing need to share process information in addition to product data. Software applications range from those that simply portray processes graphically to tools that enable simulation, planning, analysis, scheduling, and/or control of processes. In collaboration with industry and academia, NIST is developing a Process Specification Language (PSL) that will be common to all manufacturing applications, generic enough to be decoupled from any given application, and robust enough to be able to represent the necessary process information for any given application. Additionally, the PSL will be sufficiently well-defined to enable exchange of process information among established applications.

NIST is requesting proposals for computer-based tools to facilitate the use of the PSL for process modeling and process information exchange. Proposals should target the specification and design of generic PSL-based development and integration tools or extensions to manufacturing application software. Solutions could involve the

development of translators or wrappers for exchange, or tools for creating and editing PSL presentations.

References:

http://www.nist.gov/psl/

Schlenoff, C., A. Knutilla, S. Ray. 1996. Unified Process Specification Language: Requirements for Modeling Process. NISTIR 5910, National Institute of Standards and Technology, Gaithersburg, MD.

8.9.8T SUBTOPIC: Analyzing Manufacturing System Performance through Architectural Formalization

The NIST Intelligent System Division has been developing the Intelligent System Architecture for Manufacturing (ISAM), which forms the basis for manufacturing systems, such as the Next Generation Inspection System Workstation and the Hexapod of the NAMT. NIST plans to further develop and apply ISAM to many other complex manufacturing systems. Being able to analyze system performance, completeness, and consistency of systems designs would greatly enhance a user's ability to develop and deploy ISAM based systems.

The first step in achieving this goal is to use a formal language, such as Z, an architectural description language, such as Rapide, or a robust software engineering paradigm, such as an Object Oriented method, to describe ISAM. Once described, compiler-like tools can be generated to check the architecture for completeness, compliance, and consistency. Problems such as a particular data requirement not being accounted for can hopefully be detected.

A second step is to develop a toolset that can "execute" the formally described system to examine the correctness of a system's performance. Issues such as whether a goal state is reachable and the degree of redundancy that exists in the system can be examined.

A third step is to develop a compiler to convert the formally described system design to conventional computer code, such as C++.

NIST is soliciting proposals that either develop a formal language/software engineering paradigm or apply an existing set to describe ISAM. The deliverable for the Phase 1 should include a description of ISAM within the language/software engineering paradigm, and the first version design of the aforementioned toolset and compiler.

8.9.9T SUBTOPIC: Ontological Engineering Applied to Manufacturing System Integration Research

The Manufacturing Engineering Laboratory is soliciting proposals for the application of the principles behind ontological engineering towards the area of manufacturing systems integration and/or research. The result of this effort will either be: (1) mechanisms, infrastructures, and/or methodology tools with an ontological underpinning that will facilitate the interoperability of manufacturing systems; or (2) the application of ontological principles towards the creation of an electronic notebook, as described below. Within the former area, these principles may be applied to information that is to be shared among manufacturing applications, including, but not limited to, process, resource, product, and design information. Special emphasis will be given to proposals that are applicable to multiple types of information.

The implementation of an ontology-based electronic notebook system (option 2), should allow researchers to collaborate, build, and review domain-specific ontologies and knowledge bases. The implemented system should demonstrate its applicability to a collaborative engineering or manufacturing setting. Each ontology and associated knowledge base(s) [the data] is inherently domain-specific. However the electronic notebook system itself should be domain independent. The system must be based on knowledge representation and interchange formats which permit interaction and possible integration with other such knowledge systems, e.g. KQML and KIF. The use of agent technology is recommended to coordinate and integrate cooperating researchers' electronic notebook entries, and to facilitate integration with other knowledge systems. The user interface(s) should be platform-independent, and other system components should be platform portable. It is expected that a proposed system should leverage prior work in the field of electronic notebooks.

In the context of this proposal, an ontology is an explicit treatment of some topic. It is a formal and declarative representation which includes the vocabulary (or names) for the terms in that subject area and the logical statements that describe what the terms mean and how they can or cannot be related to each other. Ontologies, therefore, provide a formal means for representing and communicating knowledge about some topic and a set of relationships that hold among the terms. Without these formal and concise definitions of attributes, relations, and concepts, usually built upon some type of foundational theory, integration of manufacturing applications runs the risk of misinterpretation of those concepts, leading to problems with interoperability and exchange.

References:

Toronto Virtual Enterprise Project
(http://www.ie.utoronto.ca/EIL/tove/ontoTOC.html)

Knowledge Sharing Effort
(http://www.cs.umbc.edu/kse/)

The Ontolingua Server Project
(http://ksi.cpsc.ucalgary.ca/KAW/KAW96/farquhar/farquhar.html)

Plan Ontology Project
(http://www.aiai.ed.ac.uk/~bat/ontology.html)

Process Interchange Format
(http://soa.cba.hawaii.edu/pif/)

8.9.10T SUBTOPIC: Component-based Software for Agile Process Planning

Current process planning software systems are in a closed form with rigid structures. They are not only monolithic but also too generic and too complicated. Process planners find it difficult to customize these systems at the time of process planning to suit their specific and dynamic needs. These needs include, for instance, adding customized functions, changing the sequence of planning activities, integrating with related systems, and extracting needed data. A new form of process planning software is needed to allow users to rapidly develop customized software. This form of software is component-based process planning software. A software component is a functional unit, with specified algorithms, that has an open interface to communicate with users and other components. Component-based software should consist of a software library, which is comprised of components that can be easily chosen and composed into a system for process planning.

NIST is interested in the development of a software component framework to enable agile process planning that suits users' specific needs. The objective is to develop a dynamic system specification mechanism and prototype component library that will assist in developing the concept of rapid software development to meet the market demands. We solicit proposals to develop the following elements of component-based process planning software: (1) a process planning system functional and data requirement specification mechanism; (2) a library of process planning software components with clear definitions of functions, input/output data, and applied rules to each component; (3) a knowledge-based mapping mechanism that maps components to process planning requirements; (4) an automated object composition mechanism; and (5) automated software validation procedures. The principles to be developed and

demonstrated in this project will be applicable to general software development, and the framework is extensible to other application domains in manufacturing.

8.9.11T SUBTOPIC: Laser Tracker Virtual Instrument

Developed at NIST in the mid 80's, the laser tracker, a three-dimensional interferometric based coordinate measuring instrument, is a relative newcomer to the field of coordinate metrology. It is rapidly gaining acceptance as the instrument of choice for many large-scale measurement tasks by the U.S. aerospace and automotive industries. In order to maintain competitiveness in the emerging worldwide economy, many of these industry's manufacturers and suppliers have begun implementing ISO 9000 quality systems and seeking ISO Guide 25 based measurement accreditation - both of which require traceability and hence measurement uncertainty estimates. Unfortunately, the laser tracker suffers the same difficulty as all three-dimensional coordinate measuring instruments when it comes to uncertainty estimation. The error mechanisms and the way these errors propagate through the measurements process is very complex and many times task specific. Ultimately, what is required is a software package for the modeling and real time prediction of task specific measurement uncertainty. To be valid, this model must include instrument specific contributions to uncertainty (some of which are manufacturer specific), ambient environment contributions, as well as task specific uncertainty issues such as sampling strategies, size and shape of the part, distance from tracker, etc. The successful developer should demonstrate strong programming skills, a background in coordinate metrology, and direct experience with laser trackers.

8.9.12T SUBTOPIC: Intrinsically Digital Mass Measurement Technique

Research is invited on promising approaches to truly digital mass measurement techniques which do not employ analog force measuring devices, such as strain gage load cells or other analog force measuring elements with close coupled sensing devices, such as oscillating crystals, capacitive, magnetic or magneto-elastic devices. Expectations from this research, compared with existing technologies, are inherently digital mass measurement, higher accuracy, lower cost, greater environmental reliability, and independence of the acceleration of gravity.

8.10 NIST TOPIC: CHEMICAL SCIENCE AND TECHNOLOGY

8.10.1T SUBTOPIC: A Novel Atomizer for Reference Spray Combustion Facility

Combustion of chemical liquid wastes depends critically on the quality of droplet atomization, and mixing of wastes within a surrounding air flow field. A reference spray combustion facility is under development that will be used to provide benchmark experimental data. The facility will be well-characterized, and provide standards for spray systems, instrument calibration, and validation of computational fluid dynamic models. Of critical need for this facility is an atomizer that will serve as a repeatable reference standard. A variety of methodologies can conceivably be applied to ensure optimum atomization. Novel strategies are sought to provide a well-controlled spray that has known size (polydisperse) and velocity distributions, as well as predictable droplet transport properties (i.e., dispersion and penetration), and residence time under burning conditions. An atomizer is needed that will: (1) produce different *a priori* specified droplet size and velocity distributions, with known number densities (SMD between 7 and 200 µm and up to $10^6/cm^3$, respectively), (2) be applicable to high-temperature operation (combustion), (3) produce droplet velocities up to 30 m/s, and (4) use conventional fuels (e.g., kerosene) at flow rates of up to 10 l/h.

Phase 1 of this research should demonstrate the feasibility of the proposed approach. The objective of Phase 2 is the delivery of a functioning device. It is expected that the availability of a controllable spray nozzle will find immediate commercial applications in spray nozzle and burner industries.

8.10.2T SUBTOPIC: Strongly Coupled CFD Code for Modeling of Spray Combustion Systems

An advanced computational fluid dynamics code (CFD) is needed for detailed modeling of the complex turbulent, two-phase, flow field of spray combustion systems, such as furnaces, boilers, and thermal oxidizers. Simulations are required via numerical modeling to serve as an interface between data obtained in a laboratory-scale experimental facility and full-scale processes. Models of interest will have to deal with two-phase reacting flows in which sprays, particulates (soot), and gaseous emission species will have to be dealt with in the code. Because of the significance of the coupling effects between the fluid dynamics, chemistry, and droplet behavior, such considerations must be included in the code. The spray submodel must provide spatially resolved information on the individual droplet size and velocity distributions, number density, droplet evaporation, and dispersion. In addition to droplet tracking, the submodel should handle both the droplet transport and dynamics. The code must handle polydisperse size distributions that have a wide range of sizes from 200 µm

down to submicron droplet sizes. The chemistry submodel must enable incorporation of full chemical mechanisms. The particulate submodel must handle particle growth and agglomeration, and impingement/deposition (thermophoresis, inertial, and turbulent diffusion effects) on the chamber surfaces. Other submodels for turbulence and heat transfer between the phases (i.e., droplets and environment) must also be available in the code. Other features to be included are 1) swirl, 2) three-dimensional configurations, and 3)adaptive gridding. Computational speed and efficiency, of course, will have to be demonstrated with respect to other currently available codes.

Phase 1 should demonstrate the feasibility of developing a code with the proposed features. The objective of Phase 2 is the delivery of a functioning code. It is expected that this new modeling capability will find immediate commercial applications for fuel spray combustors, power generation systems, and chemical processes involving combustion of liquid wastes.

8.10.3T SUBTOPIC: Particle Image Velocimetry (PIV) for Flow Measurement

Accurate, non-intrusive flow measurement techniques are needed at NIST to measure the flow distribution in turbulent pipe flow for liquids in closed conduits. Rapid detection of the spatial variation of fluid velocity over pipe cross sections enables computation of profile skewness and swirl, both of which are critical in assessing or monitoring flow meter calibration conditions. Profile skewness and swirl can significantly affect the performance of flow meters, and these profile characteristics can propagate considerable distances downstream from pipeline elements, such as pipe elbows, valves, etc., which produce these flow phenomena. NIST seeks research and development to extend current Particle Image Velocimetry (PIV) techniques to rapidly measure the fluid velocity distribution over pipe cross-sections in turbulent flows of transparent liquids. The desired system should be capable of producing spatial and temporal correlations of the resulting velocity information to assess profile characteristics and monitor bulk flow steadiness. The measurement accuracy goal for point velocities over the pipe cross-section is: (1) $\pm$ 1% or better in the ideal velocity distributions produced by long straight lengths of constant diameter piping, and (2) 2% or better for skewed and swirled pipe flows, such as those which flow from pipe elbows or valves. Phase 1 should produce a system design, an estimate of its uncertainty, and

a feasibility study of its capability to assess pipe flow profiles. A Phase 2 effort to develop a functioning prototype of the system will be considered based on the results of Phase 1.

8.10.4T SUBTOPIC: High Temperature Thin-film Insulation

High temperature (900 °C) thermometry and heat flux gages require high temperature thin-film insulators. The gages may employ noble metal thermoelements such as platinum, palladium, and rhodium alloys, or heat resistant nickel alloys. Although some success has been obtained using sputtered oxide coatings, several problems interfere with commercial applications. Commercial insulators are limited by low melting substrates, such as anodized aluminum, high cost sputtered oxide techniques, and pinholes and flaws in CVD and sputtered coatings. The ideal coating would be less than four micrometers thick; defect free, with a high dielectric breakdown voltage; inexpensive to deposit on a variety of metal substrates of various shapes; well bonded to the substrate and the thin film conductors above; and stable in the environment of the application.

Proposals are sought for innovative methods to achieve the fabrication of low cost, high temperature thin-film insulators. These insulators should be capable of electrically insulating thin-film sensors from metallic substrates at temperatures ranging up to 1100 °C, with a thickness of less than four micrometers. The thin-film insulator should be compatible with stainless steels, high temperature nickel-based alloys, and noble metals, such as platinum and palladium. Application in the temperature range of 500-800 °C are also important and will be considered. The planned project should demonstrate the fabrication of the thin-film insulator on suitable substrates, including silicon, for thermocouples and heat transfer gages and demonstrate, also, the performance of the insulating film. A plan for commercialization of the process is also important.

8.10.5T SUBTOPIC: Mid-Infrared Light Source for Cavity Ring-Down Spectrometer

NIST is developing cavity ring-down spectroscopy as a quantitative method for making accurate and precise measurements of gaseous contaminants in ultrahigh vacuum environments and process gases. For optimal sensitivity, mid-infrared laser sources are needed. For optimal impact, these sources should be simple and rugged enough for use in industrial environments. Target gases include H_2O, O_2, CO_2, CO, and CH_4. The ideal laser would be tunable to one or more absorption resonances of several of the target gases; a Phase 1 project should focus on the 1.4 µm (v_1+v_3) or 2.7 µm band (v_1 and v_3) of water and the 1.3 µm band ($a \leftarrow X$) of oxygen. This source could be pulsed, with a pulse duration of 10-50 ns, a repetition rate of $\geq$1 kHz, and an output power of

≥100 mW in a TEM_{00} mode. The output radiation should have a spectral bandwidth of ~100 MHz, and a frequency drift of ~100 MHz per hour. The laser should be operable for extended periods without the intervention of skilled personal, and it should be rugged, spatially compact, air cooled, and run on 110 V_{AC} electrical service.

8.10.6T SUBTOPIC: New Technology Detectors for Analytical X-ray Spectrometry

NIST has a long standing interest in analytical X-ray spectrometry, with excitation beams of electrons or photons. Energy dispersive X-ray spectrometry (EDS) is generally preferred, due to its capability of viewing the entire X-ray energy spectrum and, therefore, of performing a complete qualitative analysis at each beam location. Existing EDS detectors, based on large monolithic semiconductor crystals (Si, Ge) are limited in resolution (130 eV for Si; 120 eV for Ge, both at 5.89 keV, Mn K-alpha), in photon processing speed (about 3,000/s at the best resolution), and size (10 square mm for the best resolution). Additionally, these detectors must be cooled to approximately 100 K, which places constraints on their integration into complex electron beam systems, such as microscopes.

NIST is interested in developing analytical X-ray spectrometry, based upon other possible approaches to X-ray detection. Recent presentations at scientific conferences have suggested the possibility of using detectors based upon silicon drift technology, which have the possibility of higher resolution, larger surface area (100 square mm), much higher rates of photon processing (> 100,000/s), and operation at or near room temperature. NIST, therefore, seeks proposals to develop the methods of fabricating practical detectors for analytical X-ray spectrometry based upon this or similar concepts.

Reference:

Strudar, L. 1997. High Resolution Non-Dispersive X-ray Spectroscopy with State of the Art Silicon Detectors. European Microbeam Analysis Society, May 15.

8.10.7T SUBTOPIC: Telepresence Electron Microscopy and Microanalysis Systems

NIST solicits proposals for the development of methods to connect sophisticated electron microscopy and microanalysis instrumentation to remote collaborators and users, based upon any of several different levels of communication technology, ranging from basic television signal transmission via modem/telephone lines to the high speed ATM network capabilities. In recent years, intensive efforts by manufacturers have established local control systems for computer-assisted operation of these instruments, especially the imaging and microanalysis features, such as electron imaging systems,

X-ray spectrometry, and electron energy loss spectrometry. Development of the methodology, software, and interfacing protocols to establish long distance observation and operation that will enable effective collaborations to operate in real time, between scientists and engineers located in industry, academia, and national laboratories.

Electron microscopy and microanalysis is a critical measurement technique that has a major impact on the development of new materials, development and trouble shooting of processing and manufacturing for materials and devices, and failure analysis of finished products. Measurements include micrometrology of two- and three-dimension spatial features, chemical characterization of elemental species and compounds in the microstructure at the micrometer to nanometer spatial scales, and crystallographic (phase) determination. Critical industries affected include primary users as diverse as semiconductor devices, communications, petroleum, and pharmaceuticals, and secondary users such as aircraft (e.g., failure analysis), fluid power (particle loading in engine oil), and biomedical (e.g., device-tissue interactions). Implementation of these techniques typically requires capitalization at $0.5 - $2.5 million per commercial instrument, plus additional costs for Ph.D. level personnel to operate, or direct, the use of the instruments. As a result, only the largest companies can afford to directly purchase and implement these techniques "in house", and then only at central R&D facilities, remote from at least some of their manufacturing centers, while smaller companies are nearly always forced to use remote suppliers of analytical services. NIST solicits proposals for the development of computer control and communication capabilities to implement "telepresence" microscopy and microanalysis, whereby instruments can be monitored in an "over the shoulder" mode of operation and analysis with collaborators and, in some cases, the instruments operated by remote users. Successful development of telepresence operation will bring important capabilities and new efficiencies to U.S. industry, and new measurement strategies to NIST. Telepresence capabilities will be of particular value to commercial providers of "service analysis" by greatly improving connections to customers.

8.11 NIST TOPIC: PHYSICS

8.11.1T/A SUBTOPIC: Artifact for Characterizing Scanning Surface Inspection Systems

Commercial scanning surface inspection systems, or wafer scanners, rely upon optical scattering to determine microroughness and particulate contamination parameters of silicon wafers. However, due to its unique optical geometry, each instrument is sensitive to a different range of spatial frequencies of surface microroughness, with a different sensitivity to each spatial frequency within that range. Furthermore, that sensitivity may change over time, due to aging or misalignment of the optics.

NIST seeks proposals for development of an artifact which would allow the spatial frequency response function for a scanning surface inspection system to be measured. An example of such an artifact may take the form of a silicon wafer on which has been patterned a series of gratings of known amplitudes spanning a range of periods and orientations. The number of different periods and orientations would have to be sufficient to characterize any commercially available system, and the scattering levels must be sufficiently low so as to not saturate the system being characterized. Other configurations are possible, but sufficient information must be available to obtain the response function for isotropic microroughness.

Microroughness is also extremely important in the quest for increased storage capacity and smaller disk-drives. For example, if the surface roughness is increased, then the flying height needs to be increased to prevent head crashes. Since flying height is the primary factor that determines practical areal recording density, this limitation is a serious barrier to further improvements in storage capacity for digital data storage drives. ATP has funded approximately a dozen projects in data storage technology. Most, if not all, require attention to roughness of heads, media, and substrates. A microroughness artifact would be valuable for the data storage community that is seeking uniform metrology to achieve smoother and flatter head air-bearing and disk surfaces.

8.11.2T/A SUBTOPIC: Bidirectional Ellipsometer for Surface Inspection

The quantity of light scattered by a material is often a useful measure of the quality of its surface or bulk. However, it is usually difficult to unambiguously determine the source of scatter, be it from surface microroughness, subsurface defects, or particulate contamination, just from measurements of the intensity of the scattered light. The

polarization of the scattered light, on the other hand, contains information about the sources of scatter, since it more strongly reveals the path the light followed during its trajectory. The technique of bidirectional ellipsometry, whereby the polarization of light scattered by a sample is measured in directions out of the plane of incidence, has been found to discriminate between light scattered by particulate contamination, subsurface defects, and microroughness. Predictions for polarized light scattering in dielectric films and simple structures on silicon or metal surfaces have suggested that bidirectional ellipsometry will also prove powerful for characterizing defects in layered or patterned materials.

Proposals are sought for the development of instruments which will allow industry to rapidly make use of bidirectional ellipsometry for the characterization of defects in materials. Numerous commercial instruments exist for performing spectroscopic or multiple-angle ellipsometry, and these instruments are used regularly for the measurement of thin film thicknesses and dielectric constants. Due to the novelty of bidirectional ellipsometry, no commercial instruments exist at this time for readily performing it.

Integration of optical and electronic devices on a single chip in the form of an OptoElectronic Integrated Circuit (OEIC) promises to produce products that are more reliable, more complex, faster, and more affordable than ever before. Optical thin films of non-linear optical materials such as lithium tantalate are used in the construction of optical devices, much in the same way that electronic integrated circuits are assembled using existing semiconductor technology. Optical waveguides, switches, modulators, and second harmonic generators are components of the optical devices that will have a tremendous influence over future developments in both communications and computing applications. However, the performance of these nonlinear devices may be severely degraded by scattering mechanisms. Bidirectional ellipsometry may be a powerful tool to gain insight into these degradation mechanisms. In addition, the technique may be useful in characterizing other factors that may increase attenuation of the guided wave, such as optical absorption, porosity, and refractive index inhomogeneities, such as those found in polycrystalline materials. ATP has funded several projects which developed nonlinear optoelectronic components for wavelength multiplexing signals through optical fiber communications systems and the frequency doubling of light for applications in high-resolution displays, optical storage devices, and printing applications.

8.11.3T/A SUBTOPIC: Microfabricated Cantilever Probes for Combined Near-Field Scanning Optical and Atomic Force Microscopy

Near-field scanning optical microscopy (NSOM) is rapidly becoming a useful technique for nanoscale optical characterization of materials. NSOM makes use of the properties of a sub-wavelength optical probe to exceed the diffraction limit in optical microscopy. Images are constructed by scanning the probe over a surface at distances much smaller than a wavelength of light. Contrast is generated by way of a number of different interactions of the sample and probe, including such traditional optical contrast mechanisms as absorption, reflection, fluorescence, and polarization, and also new contrast mechanisms that are unique to NSOM, including dielectric contrast. Probes currently in use for this purpose include single mode glass optical fibers drawn to a fine point (about 50 nm) and usually partially coated with aluminum, and small metallic scatterers.

NIST is seeking microfabricated aperture, waveguide, or combination aperture/scatterer NSOM probes in a form that is compatible with atomic force microscopy (AFM). These probes should be useable as contact, noncontact, or intermittent contact probes in commercially available atomic force microscopes, but should have the additional feature of a small subwavelength aperture or tapered waveguide structure for guiding and confining light. Waveguide or aperture probes with a small scatterer at the tip will also be considered.

Newer data storage devices are exploring the concept of recording more than one bit of information per physical location on the media. For example, one project funded by ATP relies on a variable-depth pit in a substrate to encode information in a very dense array of spots similar to those on a CD-ROM. The cantilever probes for combined near-field scanning optical and atomic force microscopy may lead to a powerful combination of measurement and diagnostic tools that will have market applications in the data storage industry.

8.11.4T/A SUBTOPIC: Standard Reference Materials and Resolution Test Patterns for Characterization of Scanning Near-Field Optical Microscopes

Near-field scanning optical microscopy (NSOM) is rapidly becoming a useful technique for nanoscale optical characterization of materials. NSOM makes use of the properties of a sub-wavelength optical probe to exceed the diffraction limit in optical microscopy. Images are constructed by scanning the probe over a surface at distances much smaller than a wavelength of light. Contrast is generated by way of a number of different interactions of the sample and probe, including such traditional optical contrast

mechanisms as absorption, reflection, fluorescence, and polarization, and also new contrast mechanisms that are unique to NSOM, including dielectric contrast. Because of these optical contrast mechanisms, NSOM could have significant applications in metrology for magnetic and optical data storage materials, particularly in cases where STM or AFM contrast mechanisms may not be applicable.

NSOM probes currently in use include single mode glass optical fibers drawn to a fine point (about 50 nm), and usually partially coated with aluminum and small metallic scatterers. Probes can be used either for collection of light or for illumination of the sample. Resolution in NSOM depends on the size and efficiency of the probes, and is intimately tied to the contrast mechanism used. No standard techniques or materials exist for determining the resolution and characterizing the contrast mechanism of these probes.

NIST is seeking proposals for development of suitable reference materials and resolution test patterns to determine the resolution and characterize the contrast mechanisms of near-field probes. Suitable materials will have nanoscale optical features that have little or no topography, and will be useful for characterizing probes used in reflection, absorption, polarization, fluorescence, or dielectric contrast.

8.11.5T/A SUBTOPIC: Attenuated Total Reflection (ATR) for Far-Infrared Spectroscopy

Research into novel spectroscopic applications of far infrared radiation (THz regime at >50 microns or <200 cm-1) is of current interest to NIST, industry, and academic research groups throughout the US. Included in these rapidly growing areas is the ability to detect minute transmission changes (0.1% change or less per reflection) of weakly absorbing thin films, organic and biochemical monolayers deposited on transmissive substrates, or of molecular systems dissolved in highly absorbing solvents. A widely-used, generic approach for obtaining high sensitivity, broadband mid-infrared spectra (2-25 microns) of these sample types with commercial FTIR instruments employs attenuated total internal reflection crystal accessories (ATR's). These devices are designed to accept radiation via FTIR transfer optics and permit multiple reflection passes of the infrared beam through appropriately cut ATR crystals in contact with the sample. Typical crystals used in mid-IR work include high refractive index ZnSe, Ge, or KRS-5 glass, which are only transmissive to <25 microns.

Proposals are sought for development of an ATR-type device for far-infrared spectroscopy of organic and biochemical monolayers adsorbed on silicon-oxide or other oxide substrates. The goal of this SBIR is to design and engineer an appropriate ATR crystal substrate to obtain the maximum number of reflection passes in a minimal crystal path length, and reduce beam walk-off and divergence through the crystal path

at long IR wavelengths. The device must couple to a commercial far-infrared FTIR or collimated broadband radiation generated by a laser-based THz system. One possible material is high purity silicon which provides minimal transmission loss, has a high refractive index and is capable of surface modification to form silicon-oxide. Other materials are also possible, as would unique designs with compensating input and output focussing optics to maintain beam collimation and throughput. It is envisioned that an accessory of this type, currently unavailable on the commercial market, will become desirable and widely used in future FTIR systems.

8.11.6T/CC SUBTOPIC: High-Resolution Two-dimensional Active Electronic Neutron Detectors

NIST uses two-dimensional neutron imaging detectors for several important applications: neutron radiography, neutron tomography, neutron phase contrast imaging, small angle neutron scattering, neutron reflectometry, and neutron beam diagnostics. In most of these applications where active electronic imaging devices are employed, improved resolution is very badly needed. Ironically, microchannel plate neutron detectors were first developed at NIST and received a R&D100 Award, but now we have to import them from Germany and Russia, due to lack of commercial development in the United States.

NIST has purchased several of these microchannel plate devices with 40 µm resolution from a German supplier, and we have borrowed a 9 µm resolution microchannel plate detector of Russian origin from a German collaborator. Our most demanding current use of these two-dimensional imaging devices involves high-resolution radiography of hydrogen fuel cells, which are being developed for new-generation automobile power sources.

The objectives of proposals on the subtopic should be to develop active electronic neutron detectors and fabrication techniques which provide improved resolution, improved efficiency, larger active area, and reduced cost.

Passive image accumulation devices are also of interest to NIST, but current products of this kind are already much more satisfactory, and the present subtopic pertains only to active electronic devices.

8.11.7T SUBTOPIC: Analysis Software for Near-Field Scanning Optical Microscopes

Near-field scanning optical microscopy (NSOM) shows great promise as a new optical microscopy which can provide resolution much better than the diffraction limit. In NSOM, a single-mode optical fiber is pulled and tapered to a tip and then coated with metal, leaving a small nm-scale aperture at the tip end. This tip can act either as a nm-scale source or collection aperture. When the tip is placed a few nanometers from a sample, nm-scale resolution can be obtained. NIST currently has a long-term program to develop NSOM and to exploit it in metrological applications.

The optical interaction between the probe tip and the sample occurs in the near-field regime. As a consequence, rapidly varying evanescent fields make critical contributions, and the tip and sample are strongly coupled by the fields. New paradigms and simulation capability must be developed to analyze optical microscopy in the near-field regime. No routine quantitative near-field microscopy can be done until the software tools are available for system optimization and control, and data analysis and interpretation.

NIST is seeking innovative approaches that can be developed as software products. Such approaches should provide full three-dimensional modeling of the vector electromagnetic fields in an interacting tip-sample geometry by the solution of Maxwell's equations. The optical response of the tip and sample should be modeled by complex dielectric response functions. The approaches should be able to treat a wide range of tips and a variety of samples, including, for example, optical waveguide devices, periodic and structured arrays of dielectric objects, isolated molecules, and quantum nanostructures. The approaches should be able to model the images, typically detected in the far field, that are generated by the near-field tip-sample interaction, and account for the transfer of probe light from far-field sources into the tip-sample interaction region. A key challenge is to develop approaches that are efficient and robust, so that simulations can be used to analyze data and optimize microscope operation in near real time. It is expected that innovative approaches will be developed that exploit the power of sophisticated numerical techniques, such as finite difference and finite element methods, needed for three-dimensional solutions of the vector Maxwell equations for complicated structures, while providing the efficiency and robustness needed in an effective simulation tool.

8.11.8T SUBTOPIC: Vacuum Near Field Optical Microscope

For a variety of measurement applications in nanometer scale semiconductor devices, such as measurements of photoluminescence, study of wafer defects, and examination of photoresist materials, an ultrahigh vacuum near field optical microscope instrument is required. The design of the instrument must incorporate standard optical fiber tapered tips with easy interchange of both tips and samples under vacuum. The instrument must incorporate shear force topographic imaging, vibration isolation, and high efficiency light collection in transmission and reflection modes of the near field optical microscope. A resolution of 100 nm is desired. The near field instrument and its vacuum chamber and pumping system will be mated to standard surface science ultrahigh vacuum equipment used for deposition and analysis, with compatible load lock sample introduction and transfer. In Phase 1, a complete engineering design of the vacuum near field optical microscope and its associated vacuum chamber, sample and tip manipulation devices will be required as a deliverable. In Phase 2, delivery of a working vacuum near field optical microscope, associated electronics and software, and representative data scans would be required.

8.11.9T SUBTOPIC: Advanced Ion Beam Methods for Nanotechnology

Ion beams are finding increasing application in various subdisciplines of nanotechnology, including:

1. Microelectronics: A typical microelectronics production line uses ion beams in over a dozen separate fabrication steps. In addition to conventional ion implantation methods, which have been in use for decades to form bipolar transistor bases, more modern uses include trench isolation, preamorphisation, proximity gettering, well engineering, and ion beam synthesis of buried layers. In addition, ion beams are used in microelectronics prefabrication to help construct working prototypes, and in post-production to diagnose failure. Future applications for online diagnostics and reduced-dimensionality lithography are envisioned.

2. Biotechnology: Material damage caused by the passage of a single energetic ion can produce nano-scale pores in materials, which can be used in the production of selective membranes for drug delivery and other applications in biotechnology.

3. Photonics: Production of advanced flat panel displays, diode lasers, and optical waveguides are examples of areas in which ion beams are showing increasing promise. Although miniaturized photonic devices typically have overall dimensions greater than one micron, they often rely on nanoscale uniformity or substructure.

NIST is seeking proposals for innovative ways to produce and apply ion beams for use in the general area of nanotechnology. Work should be geared toward results that lead to significant device performance improvements or lower manufacturing cost when compared to established alternative methods. Proposals which take into account the effect of varying the ion charge are particularly encouraged.

References:

Sealy, B.J. and P.L.F. Hemment. 1994. Ion beam techniques in microelectronics. Nucl. Instrum. Meth. Phys. Res. B, **89**, 298.

Reber, N. et al. 1995. Thermal Switching of grafted single ion tracks. Nucl. Instrum. Meth. Phys. Res. B, **105**, 275.

Polman, A. et al. 1995. Ion beam synthesis of planar opto-electronic devices. Nucl. Instrum. Meth. Phys. Res. B, **106**, 393.

8.11.10T SUBTOPIC: Quantitative Software Modeling and Verification of Roughness-Dependent Emissivity for Rapid Thermal Processing

In the rapid thermal processing (RTP) of silicon wafers, temperature and temperature uniformity are critical measurements that depend on an accurate knowledge of the emissivity of the wafer surface over a wide range of temperatures, angles, and radiation wavelengths. The emissivity, in turn, is a complicated function of the surface roughness, which can result in non-uniform radiative cooling of the wafer and create temperature non-uniformities. If the wafer surface is perfectly smooth, the emissivity is simply one minus the Fresnel intensity reflection coefficient. Real surfaces, however, are rough to some degree, and roughness affects the emissivity in a complicated way. NIST is seeking analytical software models to relate roughness variations to emissivity for a range of roughness values (appropriate to silicon wafer backsides and smoother) between 1 μm and 20 μm from 20°C to 1000°C. In addition, NIST is seeking corresponding experimental roughness and radiometry measurements to validate the analytical models.

8.11.11T SUBTOPIC: Actively Quenched IR Avalanche Photodiode

High efficiency stable photon counting devices are important for many areas of research, ranging from optical metrology, low level sensing, cryptography, and communication. All of these areas have needs in the infrared, where high quality detection is difficult to find. NIST is soliciting proposals to develop actively quenched compact photon counting modules for the spectral region from 1 to 1.5 microns or beyond with peak efficiencies of at least 50%. Such a unit would be similar to the Si-

APD based devices which have recently become available, but would likely use Ge or InGaAs avalanche photodiodes. The unit would employ an actively quenched bias circuit to reduce the avalanche recovery time, making counting rates of 1 MHz possible. The active area should be no smaller than 0.2 mm and have a dark count rate not exceeding 1 KHz. The units may use compact self contained thermoelectric cooling to produce low dark counting rates.

8.11.12T SUBTOPIC: Compact CW UV Laser Source

Solid-state laser sources are needed to replace cumbersome ion lasers as CW UV laser sources. Reductions in size of an order of magnitude and improvement in overall efficiencies of as much as three decades would greatly increase the convenience of light sources in this range and open up many new applications that are currently not possible. We are soliciting proposals for a system to produce coherent light in the range from 200 to 400 nm at power levels of 300 mW or greater. Within that spectral range, output at 213 nm, 266 nm and 355 nm, the tripled or quadrupled and quintupled output of NdYAG are of particular interest, although output at any UV wavelength will be of great utility and, of course, tunability would enhance the utility even further. The bandwidth requirement of the system should be 0.1 nm or less with fluctuations of the output power not exceeding 1%. The final device may operate by up-converting the output of existing compact solid state light sources, or may directly generate the UV if some appropriate scheme can be found. If a frequency conversion arrangement is used, the ultimate device may be integrated with the pump laser, or may be a compact add-on accessory to an existing compact light source.

8.11.13T SUBTOPIC: Line Emitting Surface LED

A commercially available line emitting surface LED would find numerous users. The source geometries now available are circular area source or square source. The availability of a small and bright line source would greatly facilitate (and make more energy efficient) the use of LED sources in a variety of position sensors. The use of an LED imaged onto a split photocell via a lens attached to the part whose motion is to be sensed (with the usual interest being in sensing motion along some particular dimension) makes an extremely sensitive and convenient one-dimensional position sensor. In our precision measurements laboratory, we have achieved motional sensitivity of 10^{-11} m for an integrating time of 1 second. However, were the "round" emitter geometry linear (a line) rather than round, we could use all the photons effectively. A desirable aspect (width to height) ratio would be something between 10 to 1 and 30 to 1. A source geometry of .005" high by 0.12" wide would be excellent.

8.11.14T SUBTOPIC: Liquid-Nitrogen-Cooled Electrical Substitution Radiometer

Electrical substitution radiometers enable accurate measurements of optical power to be made using electrical measurements, and form the basis of detector-based radiometric scales at several national standards laboratories, including NIST. They work by substituting a measured quantity of electrical heating power for optical power in alternate cycles. Room temperature versions, based on pyroelectric sensors, are available commercially, but have limited sensitivity for a growing number of applications. Liquid-helium versions are also available commercially, providing plenty of sensitivity, but at a much larger operating expense. A liquid-nitrogen cooled electrical substitution radiometer could offer a welcome compromise between sensitivity and operating expense, provided it had a high enough performance level. Typical performance specifications for a viable product should be: operable with chopped optical power with a 3 dB rolloff point of 80 Hz or greater; use of chopper synchronized electrical substitution; 5 mm or greater detector active area; spectral flatness less than 2% over a spectral band from visible to 20 micrometers; reflectance less than 1% (using, for instance, gold black and/or an optical trap); noise-equivalent-power of 10 picowatt per root Hz or less; maximum power level of 100 microwatts; and stability of response of 1% or better.

8.11.15T SUBTOPIC: Durable Ultra-Black Optical Coatings

Black absorbing coatings are used to coat optical baffles and thermal-type optical detectors. As infrared cameras, for example, are used in increasingly rugged environments, the need for durable black coatings is increasing. A coating process is desired which can coat irregular shapes, have greater that 90% absorbance over the spectral range from UV to far-IR, and can withstand long exposure to ultraviolet solar radiation without decreasing the absorbance. An absorbance mechanism based on surface morphology rather than on black dyes would seem to offer the best solution, and thus coating processes that produce particularly rough, black surfaces are desired.

8.11.16T SUBTOPIC: Ultraviolet Detectors And Optical Components

Proposals are sought for development of new ultraviolet detectors and ultraviolet optical components. These devices and components are needed because NIST has requirements to calibrate ultraviolet irradiance and radiance detectors in the spectral range of 100-400 nm for lithographic, environmental, uv processing, and space applications. These applications require uv detectors that are uniform in responsivity across the detector area and stable with time and UV dose. Also desirable are solar-blind and position-sensitive (array) UV detectors. Inseparable from the requirement for improved UV detectors is the need for UV optical components such as cutoff filters,

diffusers, and optical fibers that resist degradation under high or prolonged exposure. Commercially available components presently have poor uniformity, stability, and UV damage resistance, making it difficult to maintain calibrated instruments and transfer standards. It is also important for detectors in this spectral range to have a wide dynamic range (low noise and good linearity) and low temperature dependence of the responsivity. NIST desires the development of materials and components which have prospects for advancing the state-of-the-art.

8.11.17T SUBTOPIC: Platinum Silicide Photodiode Detectors for the Extreme Ultraviolet (Standards Quality)

NIST has been a source for radiometric transfer standard detectors for the extreme ultraviolet (EUV) spectral region for many years. Recent developments have made possible the use of radiation-hardened silicon photodiodes in this program. It is felt that the stability of NIST EUV standards can be further improved by the development of suitable detectors using platinum silicide Schottky barrier construction. Fundamentally, these would consist of a thin (<10 nm) layer of platinum silicide on n-type silicon, with a windowless configuration.

The detectors should have an active area of at least 1 cm by 1 cm, and would be used by NIST primarily in the 3 nm to 254 nm spectral region. Important parameters for NIST standards applications include a high degree of spatial uniformity and temporal stability, a low level of internal noise, and freedom from damage by radiation in the extreme ultraviolet/soft X-ray region. NIST personnel can assist in the evaluation of developed detectors in these areas.

8.11.18T SUBTOPIC: UV Fluorescence Imaging System for Spatially Selective Identification of Radicals/Molecules Important to Silicon Wafer Processing

The need for UV imaging of gas phase molecules and radicals is crucial for process monitoring in the semiconductor industry. Laser assisted or direct plasma emission from process gases is used to uniquely identify important free radicals/molecules used during etching or layering of semiconductor wafers and as a process monitor of chemical contaminants. Features of UV methods include its low background and high sensitivity (single photon detection), and fast detection of emission when used in conjunction with laser based methods. Present direct UV absorption methods provide quantitative information about these species in the form of column integrated intensities

and, thus, lack the spatial information content necessary to ensure uniform process control across the surface of the wafer.

NIST seeks proposals for innovative UV fluorescence imaging systems for spatially selective identification of radicals/molecules important to silicon wafer processing. The need for high spectral image quality on the order of 25-50 µm can be met with the use of a UV fluorescence imaging system, consisting of a UV imaging photomultiplier and spatially selective reflective optical system. The development of such a system will be invaluable to the growing need for process growth uniformity in the semiconductor wafer industry.

8.11.19T SUBTOPIC: Superconducting Quadrupole Magnet for Trapping of Ultra-cold Neutrons

NIST participates in a program of fundamental research to develop an ultra-cold neutron source. This work uses neutrons generated at the reactor facility at NIST, Gaithersburg. This new type of source is applicable to neutron beta-decay research as well as neutron scattering for materials research. The source operates using superfluid helium as a superthermal moderator and a magnetic trap to confine the neutrons.

The magnetic trap consists of two solenoids and one cylindrical quadrupole magnet. The cylindrical quadrupole magnet is the most challenging part of the apparatus. Although some work has been done in developing air-core superconducting quadrupole magnets, the technology still requires research and development. Theoretically, a trap depth of 3 Tesla or above should be attainable. Such magnets would be useful in many other areas of physics including atomic physics and atomic clocks.

The objectives of proposals on the subtopic should be to develop a viable design and construct a prototype for a 1.2-meter long, 8-cm diameter bore, air-core, >2.5 Tesla deep superconducting quadrupole magnet.

8.11.20T SUBTOPIC: Water Calorimeter for Accelerator Radiation Beam Therapy Dosimetry

Of the approximately 1 million cancers diagnosed each year, about 60% of the patients receive radiation therapy. In addition to ^{60}Co gamma-ray teletherapy sources, the radiation beams used are increasingly from electron accelerators, both in the form of the direct electron beam or in the form of high-energy photon beams, produced by converting the electron energy to bremsstrahlung in a converter plate. Therapy with such sources are performed in over 1300 clinical facilities in the US. Proton accelerators are used at two US clinical centers for the treatment of certain cancers. The absorbed dose to tumor volumes is typically 1-3 Gy per treatment; electron beam

energies are typically from 7 to 35 MeV, photon beam endpoint energies can be in the range from 6 to 30 MeV, and proton beam energies are typically from 50 to 250 MeV.

It is critical to the success of the therapy that the absorbed doses to the tissue be known accurately. The radiation doses at each facility are assured through measurements with calibrated instruments. These instruments are usually ion chambers (measuring the ionization of air by the radiation), but calibrated in terms of absorbed dose to water (a tissue-equivalent material) through calibrations traceable to NIST standards for ^{60}Co radiation. The calibration chain proceeds by a complicated protocol, based on a series of correction factors, to convert air ionization from ^{60}Co radiation to absorbed dose in water from the beam quality of interest, which contributes to uncertainties in the clinical measurements. New protocols for therapy dosimetry in US clinics will be based on primary calibrations performed directly in terms of absorbed dose to water measured by calorimetry; future trends will be toward direct, absolute absorbed-dose measurement in the wide variety of beam modalities and qualities.

The temperature rise in a water calorimeter can provide a direct, absolute measurement of the energy absorbed in water due to the radiation. A significant body of research addresses the application of water calorimetry to ionizing radiation dosimetry, the most successful of which is perhaps the work of Domen at NIST. Research and development is needed for a water calorimeter system suitable for absolute dosimetry of the radiation beams from clinical accelerators, for use at NIST in our radiation standards and calibrations program, and with potential for use at secondary dosimetry calibration laboratories, as well as at the clinical centers. The research and development should address factors pertinent to such a system, such as the accurate measurement of the small temperature rise, thermal leakage, excess heat in constituent structures, the heat defect of the water in the detector volume, motion and temperature variation of the water surrounding the detector volume, construction of appropriate housings and windows for use with accelerator beams, and control and data-acquisition systems.

8.11.21T SUBTOPIC: Monte-Carlo Interface

Non-invasive high-energy photon measurements for a multitude of applications depend on accurate instrument calibrations. The objects to be measured, however, can be very complicated and difficult to reproduce with reference materials (e.g., radionuclide distribution, matrix effects, geometry). Monte Carlo calculations offer an attractive virtual-reality alternative to physical reference materials. The major obstacle to using Monte Carlo techniques, however, is laboriously defining the geometric and material model for the environment and samples to be evaluated. What is needed is an interface software that is able to convert an AudoCad.XXX type description of the geometry and material characteristics directly into MCNP-4A (a widely-used Monte

Carlo software for radiation) for program implementation. The program should be coded in C, user friendly, and seamless between AutoCad.XXX and MCNP-4A. Presently, simplistic Monte Carlo programs are used only by specialists because of the complicated nature of defining the radiation environment. The requested software will allow wider use of the powerful Monte Carlo technique for much more sophisticated and complex applications. The software will open new commercial opportunities for radiation measurements, and associated disciplines.

8.11.22T SUBTOPIC: Automated Glow-Discharge Source for Mass Spectrometric Counting of Radionuclides

NIST is responsible for the development of low-level, natural matrix standards, and the correct application of these standards to environmental radioactivity measurements. A glow-discharge source has been investigated at NIST for use in mass spectrometric measurements of radionuclides, and shows significant potential for highly sensitive measurements using little or no radiochemistry.

This proposal is to develop a glow discharge source, or equivalent, or better, with optimization of the basic parameters, to give acceptable sensitivity, and to develop a commercially useful design that can incorporate environmental samples on an automated basis. Such a device has enormous potential commercial value, since a significant fraction of future environmental measurements will be performed by mass spectrometry systems, and this device could be crucial in developing an automated mass-spectrometric system.

The device would be coupled to a Resonance Ionization Mass Spectrometry system which uses c.w. lasers for the atom selection. The aim is to provide a mass selection in the 10^{-13} range.

8.12 NIST TOPIC: MATERIALS SCIENCE AND ENGINEERING

8.12.1T/A SUBTOPIC: Development of Particulate Control in Pulsed Laser Deposition of Thin Films

Pulsed laser deposition is an emerging technique for the production of complex novel thin films of interest to the semiconductor and photonics industries. Commercialization of pulsed laser deposition is limited in part by particulate formation during the

deposition process. The elimination of these particulates is crucial to the incorporation of these complex films in integrated circuit devices. Innovations are needed for the control and elimination of particulates during the pulsed laser deposition process.

8.12.2T/A/I SUBTOPIC: Software for Analysis of Acoustic Microscope Signals

According to U.S. Patent Number 5549003, obtained in 1996 by the Metallurgy Division of NIST, the shear acoustic mode created at a water/solid interface by mode conversion and propagation in the solid is sensitive to residual or applied stresses in the solid. The feasibility demonstrations of stress measurements using this effect were first published in JASA and in Nature. The major obstacle which impedes this technique from becoming a routine tool for stress measurement by use of an acoustic microscope is the technical difficulty of separating the longitudinal wave reflected twice from the shear wave reflected once, since these waves arrive simultaneously at the receiver. The interference problem for birefringent shear waves propagating in the material

technologically important magnetic materials, such as spin-valves, ultra thin multilayers, and granular systems. The MOIF film is placed on top of a magnetic sample and has its magnetization altered by the magneto-static field of the sample under study. The domain structure of the magnetic sample can then be imaged in a polarizing microscope through the interaction of polarized light with the MOIF film. The MOIF method is expected to become a standard non-destructive quality control imaging technique for the next generation of magnetic materials for sensors and storage devices. Proposals are solicited for the development of improved magneto-optical indicator films, including, but not limited to, transparent bi-substituted yttrium-iron garnet single-crystal films (thickness 1 - 3 micrometers, Faraday rotation > 100,000 deg/cm), with a reflective Al underlayer grown on a gadolinium-gallium garnet substrate. The influence of different element substitutions should be studied to enable films with different magnetic saturations and sensitivities to be fabricated.

Reference:

Gornakov, V.S. V.I. Nikitenko, L.H. Bennett, H.J. Brown, M.J. Donahue, W.F. Egelhoff, R.D. Mc.Michael and A.J. Shapiro. Experimental study of magnetization reversal processes in a nonsymmetric valve. J. Appl. Phys. 81. (8) 5215.

8.12.4T/A SUBTOPIC: Advanced Measurement Technology for Characterizing the Dimensional Stability of Thin, Small Area Dielectric Films

It is no longer unusual for semiconductor packages, interconnect substrates, or other electronic subsystem to incorporate a wide variety of materials with thickness dimensions ranging from a few hundred nanometers to tens of microns. These developments, in conjunction with the diversity of materials being utilized, requires a concurrent availability of suitable measurement tools for the characterization of material properties, and the determination of product-process interrelationships on a scale commensurate with device feature size. These materials characterization data underpins product design specifications and reliability.

This SBIR subtopic solicits proposals for the development and commercialization of measurement equipment for the characterization of the coefficient of thermal expansion, CTE, and/or hygrothermal expansion for very thin, very small area polymer and other dielectric materials. Tools should be suitable for measuring out-of-plane or in-plane characteristics, and allow sensitive, accurate determination of fundamental material parameters for materials not to exceed 50 micrometers in original thickness, or 100 micrometers in length.

NIST capabilities in thin film z-axis dimensional stability measurements can be made available to appropriate awardees.

8.12.5T/A/CC SUBTOPIC: Next Generation Electronic Materials for High Temperature Automotive Electronic Packaging

Cost effective, high performance electronics are increasingly required in the automotive environment regardless of vehicle type. These products must withstand high temperature, vibration, wear, and abuse with reliabilities only superseded by products for defense applications. Continued *on-site* integration of microelectronic systems into automotive components, such as engine and drivetrain elements, require packaging and interconnect materials which meet industry's minimum 150^{o}C long term performance and reliability requirements.

This trend requires development and implementation of new high temperature resistant, low stress, dimensionally stable, electronic packaging and interconnect substrate polymer materials. At the same time, processes used for manipulation of these materials into electronic products must be compatible with existing manufacturing pathways. Delivery and implementation of new materials must match or undercut existing cost structures.

This subtopic solicits development of new, cost effective, high temperature packaging or interconnect polymer materials for next generation packages or interconnect substrates. Proposals to develop next generation reworkable underfills, thin film dielectrics, glob tops, or anisotropic conductive adhesives are sought.

8.12.6T/CC SUBTOPIC: Constitutive Equations for Lightweight Sheet Metal Forming

Increased use of lightweight metals in automobiles is essential to the achievement of PNGV goals for improved performance. The PNGV Manufacturing Team has identified reliable and predictable aluminum forming as one of the top 5 priorities in vehicle manufacturing needs. Industrial experience with lightweight metals is limited, and the use of computer methods (for example, finite element analysis, FEA) to predict forming behavior is being actively pursued by industry to accelerate the transition from traditional alloys. FEA employs constitutive equations to relate stress and strain. However, for the large strains and nonproportional loading paths occurring during and after sheet metal forming, presently employed constitutive equations are inadequate. Advanced equations that more accurately predict the mechanical behavior of metal undergoing large strain plasticity need to incorporate internal state variables. We seek the development of equations incorporating measurable, physically based state

variables (for example, parameters describing dislocation structures). It must be demonstrated that effective techniques exist or can be developed for non-destructive measurement of these variables and the internal state of deforming metals. Such an approach is likely to be useful in a variety of commercial applications ranging from the determination of residual stress to metal forming.

8.12.7T/CC SUBTOPIC: Process Monitoring and Control of Composites Processing

Composites manufacturing is a growing industry in the United States. However, quality control issues threaten to limit the growth of the industry in high production volume commercial sectors such as automotive. Inconsistency in part quality arises from a large number of sources, including catalyst, mixing, and resin variabilities. Another important source of inconsistency arises from flow variability caused by fiber preforms that do not perfectly fit mold contours. Process monitoring and control are expected to improve quality and drive down production costs.

Researchers at NIST have developed prototype optical fiber sensor systems for fluorescence and near IR monitoring of composites processing in response to industry needs for improved process control. NIST seeks proposals to explore the usage of optical fiber process monitoring systems for process control in liquid molding or pultrusion manufacturing environments. Proposals are also sought to refine, ruggedize, and miniaturize the optics and detector systems.

The current optical fiber fluorescence system can obtain complete spectra in under 0.1 s, in either distal or evanescent wave sensing mode, and has been laboratory tested with epoxy, polyurethane, and isophthalic polyester resins. The optical fiber near IR system uses the same inexpensive fiber as the fluorescence system, and is currently implemented with a standard FTIR. Evanescent wave near IR spectra are obtained in less than 4.5 s.

8.12.8T SUBTOPIC: Sensor for *In-Situ* Measurements of Thermal Spray Coatings

Thermal spray coatings are becoming more important as manufacturers simultaneously search for techniques for cutting costs and giving their parts and products greater reliability and wear resistance. To succeed, the manufacturers require measurement and diagnostic tools to better understand and control their processes. A sensor that gives more accurate temperature measurements, provides an indication of changes in texture (emissivity), and also gives an indication of coating quality, would be important in extending the applicability and reliability of thermal spray coatings. Researchers at NIST require a sensor or sensors to make localized measurements of temperature,

emissivity, texture, and coating quality of thermal spray coatings. This sensor is to operate during the thermal spray coating production process, and is to be usable for feedback and control of the thermal spray process. One promising approach is the use of an optical fiber thermometer in conjunction with multicolor pyrometry and simultaneous reflectance monitoring. NIST will entertain proposals that address the major elements of this measurement problem within this framework. Ideally, the sensor would be an innovative adaptation of tried and proven technology, so that it is immediately ready to secure the required data, and is likely to succeed as a feedback and control sensor.

8.12.9T SUBTOPIC: Intermediate-Load (1 N - 100 N) Instrumented Indentation Tester Development

The experimental technique of instrumented (or "depth-sensing") indentation is rapidly becoming the test method of choice for the measurement of mechanical properties, such as Young's modulus and hardness in small volumes of material. In this technique, an indenter tip is loaded onto the surface of a specimen and then unloaded, and the load on, and displacement of, the tip into the specimen are monitored continuously throughout the indentation cycle. Tips are typically diamond, and can be either of spherical or sharp pyramidal (Vickers, Berkovich) geometry. The resulting load-displacement curves are then analyzed to yield the specimen's Young's modulus, hardness, and other material properties.

To date, commercial instrumented indenters fall into two classes: those designed to operate at low to very low loads (from 1 N down into the microNewton range), and those based on universal test machines operating at several hundred to several thousand Newtons. The intermediate range of 1 N to 100 N is unavailable to purchasers of commercial machines, and the few researchers working in this regime must work with home-made devices. This gap in testing ability is significant, as it is the indentation load that determines the length scale over which mechanical properties are measured. At a load of 1 N, for example, indentation depths in glasses and ceramics are typically only a few micrometers, with contact areas between the tip and specimen on the order of 10 micrometers squared. While a probe on this length scale is appropriate for very thin films and fine-grained materials, there are many materials with coarser structure, such as plasma-sprayed coatings and composite materials, where much larger volumes must be sampled in order to correctly assess bulk material properties. The Ceramics Division has built a device for operation in this range, and although it is being used extensively, it has fundamental limitations in accuracy and

flexibility of use that severely restrict its utility. It is believed that a commercial machine of the type specified below would constitute a very viable product. We routinely receive calls asking how NIST data in this load range were obtained, and whether there is a commercial product available for this load range.

There is also currently no instrumented indenter in any load range that permits indentation of specimens at elevated temperatures. Since many material properties are strongly temperature-dependent, and since many materials are intended for high-temperature application, the capability to perform an instrumented indentation at elevated temperature (to 800 - 1000°C) is highly desirable. It is understood, however, that this design constraint severely complicates the machine design, and it is included here as a highly desirable, but not essential, component of the design.

The purpose of this proposal is to solicit the design and construction of a prototype indenter to operate in the 1 N to 100 N load range. The machine should be designed to meet the following specifications and performance criteria:

Load range:	1 N - 100 N.
Load resolution:	1 mN or 0.1%.
Displacement resolution:	1 nm.
Indentation location:	An optical system must be included, such that the location of an indentation can be preselected with approximately 1 micrometer precision on the specimen surface.
Operational control:	Operation of the system must be under computer control, such that all aspects of the indentation cycle (loading rate, maximum load, hold times, reloading, etc.) can be programmed in advance of the measurement.
Temperature range:	Specimen and indenter tip temperature from room temperature to 1000°C.

8.12.10T SUBTOPIC: Software for Optimization of Ceramic Lapping and Polishing

Lapping and polishing processes are used in industry as the final machining step to produce the desired geometrical form and surface finish. In the lapping and polishing operations the work-piece is pressed against a lapping plate, and a slurry containing abrasive particles in a carrier fluid (water or hydrocarbon based fluids with chemical additives) is used as the primary source for material removal. The removal of material occurs by a combination of micro-cutting and micro-fracture, and is often influenced by chemical reactions between the slurry, lapping/polishing plate, and work-piece material.

This is a highly complex process, and its optimization requires detailed knowledge of many interdependent factors. The major parameters include: the size distribution and shape of the abrasive particles, the mechanical and chemical properties of the abrasives, the chemistry and physical properties of the carrier fluid, the nature of the lapping/polishing plate, the applied pressure, rotational speed of the lapping plate, and the arrangement of the workpieces on the lapping plate. Each parameter is associated with several other variables that can influence the removal process. Optimization of the lapping/polishing process consists of finding the most appropriate set (or sets) of parameters to be used for each work-piece material, such that a desired geometrical form and/or surface roughness is achieved quickly. We invite proposals for the development of a software that can be used on personal computers for off-line optimization of lapping and polishing of ceramics and other advanced materials. The input variables could include the type of work-piece material and its mechanical and physical properties, work-piece geometry and desired dimensional form, type of abrasive used in the slurry, and desired surface roughness. The computer software would then give recommendations for the applied pressure, rotational speed, and time duration. The software must be based either on evaluated data or on a sound fundamental model, or combination of both. This software must be self-sufficient, robust, and user friendly, and it must have the potential for future modifications and expansions.

8.12.11T SUBTOPIC: Device and Technique for Measurement of Thermal Conductivity of Ceramic Powders

Models for thermal (plasma) spray and chemical processing of ceramic powders generally require thermal conductivity data for the powders. Typically data for bulk solids of the same nominal composition are used, although it is recognized that these values may differ significantly from powders. Additionally, the morphology, in terms of porosity distribution and agglomerate structure, may vary between powders of the same nominal composition. A technique and associated apparatus is desired, which can measure thermal conductivity of ceramic powders in the size range of 1 micrometer to 100 micrometers. Materials of interest include zirconia, tungsten carbide, alumina, and titania. Techniques and devices developed should be suitable for inclusion in concensus measurement standards such as ASTM.

8.12.12T SUBTOPIC: Wide Frequency Spectrometer for the Dynamic Heat Capacity

The heat capacity, which is the differential heat content of a sample as a function of temperature, can be treated as a dynamic linear susceptibility. As such it shares, with dielectric and mechanical susceptibilities, the feature of containing degrees of freedom that each relax with their own characteristic time constant τ. By analogy with these quantities, the heat capacity is frequency dependent and has real and imaginary parts. Thus, a spectrum of C_p in the frequency domain should, by means of Fourier inversion, provide valuable information for the study of thermal relaxation. However, the spectrum is not commonly available, as in the cases for dielectric or mechanical susceptibilities. There is no commercial instrument that adequately measures the frequency dependent heat capacity. Differential scanning calorimeters (DSC) have three failings: (1) they do not give absolute results; (2) they are not accurate; (3) even when they employ a sinusoidal temperature profile, they operate only over a narrow and low frequency range. A commercial wide frequency spectrometer for heat capacities is needed for the study of the thermal relaxation of polymeric material. The equipment should be low-cost, user-friendly, and operate over a wide temperature (175 K to 525 K) and a wide frequency (4 to 5 logarithmic decades, 0.1 to 10^4 Hz) range. Measurement in either time-domain or frequency-domain is acceptable.

8.12.13T SUBTOPIC: Object-Oriented Development Environment of Intelligent Process Control Strategies

The current state-of-the-art in systems for process control incorporates software tools that allow the creation of “virtual” operator controller front panels. The controller front panels contain actuators and displays that can be toggles and push-buttons, as well as dials and strip charts. The “smarts” of the controller is typically encoded in some proprietary language that may be graphical in form. This form of controller development has proven to be extremely useful, and has been widely adopted by the manufacturing community. The problem with this approach, however, is that the process control strategies still have to be developed, coded, and tested. This development process is still very expensive, and industry is eagerly waiting for solutions to this problem which will lead to a reduction in the development cycle time.

Proposals are sought for the development of an object-oriented approach to software development which reduces the development cycle time, as well as increases the reliability of the resulting code. The software tool, which is to be developed, should enable a process control operator to describe the manufacturing process in an object-

oriented fashion and to develop control strategies by distributing the intelligence of the controller among a number of concurrently executing managers, each of which will specify a control action to be taken in response to the state variables of the system.

The software tool is to take advantage of the current state-of-the-art in the areas of expert systems and fuzzy logic. The resulting control strategies developed with the object-oriented software tool, which is developed, are to be directly usable in the process controller development software tools discussed above, which are in wide use today.

8.13 NIST TOPIC: BUILDING AND FIRE RESEARCH

8.13.1T SUBTOPIC: Field Measurements of Transport Properties of High Performance Concrete

Transport processes in concrete play an important role in determining its utility, service life, and durability. Transport by diffusion and capillary suction are the primary means by which deleterious materials ingress concrete. Also, the permeability of concrete to water and gasses like radon are important in determining its utility for storage of hazardous wastes and as a barrier. We are interested in obtaining a device (or devices) which has the capability of determining the diffusivity of a molecular species, the water sorptivity, and the permeability of concrete to water or gasses in the field as a function of saturation. This device must have the capability to measure the transport properties of High Performance Concrete. For instance, chloride diffusion constants of as low as 10^{-13} to 10^{-14} m^2/s and water permeability as low as 10^{-22} to 10^{-23} m^2 may need to be determined. Other key features of this device include that it be portable, and is easy to use and make multiple measurements in the course of a working day.

8.13.2T SUBTOPIC: Intelligent Software Agent for High-Performance Construction Materials Knowledge Representation and Exchange

Efficient representation, access, and exchange of construction materials knowledge will advance the area of materials science research and use of knowledge by the construction industry. Timely, accurate, and high-quality knowledge is needed for improved decision-making. New methods must be developed and implemented that provide more efficient human to computer and computer to computer interfaces. The Building and Fire Research Laboratory is undertaking a large program that involves the

representation, integration, and dissemination of knowledge about construction materials. Knowledge within the system will be distributed and used world-wide.

BFRL is interested in the development and implementation of an intelligent software agent and architecture that will enhance the access and exchange of knowledge among industry, government, and academia. The volume and nature of construction materials knowledge will depend on innovative access and transfer methods that currently do not exist as a commercial product. Conventional information technologies (methods and procedures) do not address the current and future knowledge formats for the construction industry. An intelligent software agent must function in a distributed and heterogeneous computing environment. Leading-edge communications technologies must be used to transfer information between the human and computer entities. Databases, high-level reasoning, models, and audio/video knowledge must be communicated and presented seamlessly.

8.13.3T SUBTOPIC: Automated Knowledge Acquisition for Construction Materials Knowledge Representation and Exchange

Efficient representation, access, and exchange of construction materials knowledge will advance the area of materials science research and use of knowledge by the construction industry. Timely, accurate, and high-quality knowledge is needed for improved decision-making. New methods must be developed and implemented that provide more efficient human to computer and computer to computer interfaces. The Building and Fire Research Laboratory is undertaking a program that involves the representation, integration, and dissemination of knowledge about construction materials and systems. The major bottleneck in developing systems is the knowledge acquisition phase.

Proposals are invited for developing software tools and techniques that will support automated ontology and knowledge-base development. An ontology provides a rigorous specification to describe the relationships between the concepts of the terminology used to describe construction materials and systems, while the knowledge-base will use the specified concepts in the ontology for representing higher order knowledge. There is a need to understand the meanings and characterize differences in meanings for terms used in the construction industry, and to translate these meanings into representations that can work within a well defined knowledge sharing framework. Specific interests to this proposal include: (1) taking a machine readable dictionary and creating an ontology using automated tools, (2) taking machine readable documents and creating a knowledge-base using the constructed ontology and

automated tools, (3) taking machine readable documents and creating a machine readable dictionary using automated tools.

8.13.4T SUBTOPIC: Low-cost, Smart Vibration Sensors

If sufficiently low-cost vibration sensors were available, they could be used to shut off rotary and reciprocating machinery, such as air conditioning compressors and fans, before vibrations caused by worn bearings or other malfunctions damaged the machinery or other equipment connected to it. Low overall cost is essential for such a sensor. Low fabrication cost is required, but is not itself sufficient. All costs, which include the cost of setting up commercially viable fabrication facilities, as well as the costs of packaging, interfacing, and calibrating the sensor must be very low. MEMS technology appears to have the potential to meet these needs, but current MEMS vibration sensors are still too expensive in many of the categories mentioned above. NIST welcomes proposals for a proof of concept study that addresses most if not all of the cost issues mentioned above, as well as the technical issues of producing a vibration sensor that is robust and reliable enough for use to shut off excessively vibrating machinery in commercial settings.

8.13.5T SUBTOPIC: Visualization of Building Information

In order for the design and engineering community to utilize fire hazard analysis and performance based fire codes in developing reasonable alternatives to the prescriptive codes used today, a method needs to be developed to connect rooms and buildings in a realistic way. Such a paradigm needs to be implemented in a way that allows the user to "drag" information along with the construction connections. NIST has developed a series of models which predict the effect that a fire will have on a specific building and its occupants. The difficulty is describing complex structures sufficiently well that a designer can feel confident that the building is representative of the actual structure to be built, and an approving official can feel confident that the building which is built will indeed meet the appropriate level of safety. This means that a visual method must be developed to provide the physical connections needed for a fire model and to place people within a building. Nominally, it should be implemented in a computer-aided design package.

A computer program is needed which runs on a micro computer (IBM PC class), which will provide a visual interface to NIST fire models. It may be based on a CAD package, so long as that package is generally used in the field of building design. The implementing code should conform to the standards as promulgated in NIST reference guides, and should allow textual information and databases to be made available to the various models as the building is "constructed." Such a package would follow the standard techniques used by A&E firms in laying out buildings for visualization of

construction, but would provide the additional capability of interior connections and construction materials, which would allow an assessment of fire safety to be made. This should follow and highlight the requirements as set forth in the consolidated model building and fire codes.

References:

NIST Handbook 146, Volumes I and II. 1992. The Fire Hazard Assessment Method. National Institute of Standards and Technology.

NIST Technical Note 1299. 1993. CFAST, The Consolidated Model of Fire Growth and Smoke Transport.

8.13.6T SUBTOPIC: Sweating Thermal Conductive Performance Apparatus for Evaluation of Fire Fighter Protective Clothing

The fire service is experiencing thousands of burn injuries each year. Many of these injuries are associated with the buildup of moisture inside of the fire fighter's protective garments. Sweat and water from fire fighting activities will saturate the garments, which results in a change in their thermal performance. When the protective garments are heated by the fire fighting thermal environment, heat transfer rates increase as a result of moisture in the protective clothing. In addition, this moisture can be quickly heated to temperatures which can cause scald burn injuries.

An apparatus is needed for accurately measuring the changes in thermal performance of fire fighter protective clothing under various levels of wetting. The apparatus must have the capability of adding moisture to garment materials in a controlled fashion, with distribution and rates representative of a sweating human. The apparatus must be able to measure the thermal performance of protective garment systems, while maintaining their normal loft, and under various quantified levels of compression. The apparatus must be able to accurately measure the thermal performance of protective garments over a range of thermal environments experienced by fire fighters. The accuracy of these thermal measurements should be $\leq$ 5 %, within a single laboratory. NIST welcomes proposals which will result in the development of a robust and accurate measurement apparatus that will aid in understanding the thermal performance of fire fighter protective clothing.

8.13.7T SUBTOPIC: Water Mass Concentration Measurements in Fire and Sprinkler Driven Gas Flows

The Building and Fire Research Laboratory (BFRL) is developing models to predict the interaction of sprinklers and fires in buildings as a means to support computational evaluations of fire suppression system performance. An important variable in the model predictions and in determining the performance of fire suppression systems is the spatial and temporal distribution of water in the form of droplets from the sprinkler. Innovative proposals are solicited by BFRL for a droplet sensor to measure the local liquid water concentration in the gas flow produced by the interaction of the fire and water spray from the sprinkler. Expected temperatures in the fire driven flows are up to 500^{o}K, with droplet diameters less than 1 mm. Important considerations include spatial resolution, minimum sampling rates of 1 Hz, ease of use, robustness in fire test environments, ability for automated data acquisition, and reasonable cost.

8.13.8T SUBTOPIC: Advanced Incident Command System

Currently, many fire departments follow a prescribed protocol for handling incident command for a wide variety of emergencies. This system provides command structure and allows for the direction of all resources on the scene from a central location. Unfortunately, communication is typically limited to radio transmission. Confusion can easily occur due to miscommunication or lack of communication between the engine companies and the incident commander. Many times the resources are not positioned where they are needed the most. Or, in the case of conflagrations,it may not be clear where the resources are needed the most.

NIST has been developing a high resolution wildland/urban, wind driven fire spread computer model. When completed, the model will incorporate a wide variety of spread mechanisms and be able to run on a PC laptop. The software requirements for this model and computer capabilities should converge within the next three years.

Innovative proposals are solicited by BFRL for a PC based advance fire incident command system to provide equipment and resource tracking via GPS, and system of computer based maps onto which the results of NIST's predictive models could be overlaid. Important considerations include compatibility with the NIST model, the framework and expected input and outputs of which will be supplied to respondents, ease of use, and run time on portable windows based PCS.

8.13.9T SUBTOPIC: Integrated Fire Fighter Safety System

Fire fighters are experiencing thousands of burn injuries each year. NIST has a project to measure the "stored energy" in fire fighter protective clothing. NIST has found that by the time the fire fighter feels the heat through the gear, there is no time for corrective action, and a burn injury occurs. The fire fighter needs some type of warning system to provide time for corrective action prior to suffering a burn injury. The next step in the NIST fire fighter safety project is to develop a predictive heat transfer model based on the thermal inputs to the outer shell of the protective garment. If this predictive method could be tied into a lightweight, inexpensive, sensing, decision and warning device, many fire fighters could be spared the pain and suffering due to burns each year.

A system is needed for sensing, analyzing, and warning prior to the onset of thermal injury. This system would be robust in order to withstand the daily rigor of a fire fighting environment. Ideally, the system could be retrofit to existing gear.

8.13.10T SUBTOPIC: Rapid Scanning Near IR/IR Spectrometer

The transient, non-intrusive, simultaneous measurements of CO_2 and H_2O concentrations, soot volume fraction, and temperatures of soot and CO_2 in flame are critically needed to understand the flame structure. In order to conduct such measurements, a rapid scanning spectrometer or an array detector is required in the wavelength range from 1 to 5 microns. The concentrations of CO_2 and H_2O and temperatures will be determined by the measured emission spectra from the flame. The required spectral resolution is 15 nm, and the scanning rate (from 1 to 5 micron) should be better than 500 Hz. The field of view should be collimated to within a 2 mm diameter. The accuracy of the concentration measurement should be within ± 0.005 mole fraction, with a minimum detectable concentration of 0.01 mole fraction, ± 5% for the temperatures, with a minimum detectable temperature of 800 $^{\circ}$K, and ± 20% for the soot volume fraction, with a minimum detectable fraction of 10^{-6}g/cm^3. The device should be small enough to be easily moved from one laboratory to another by a single person without using a cart.

8.13.11T SUBTOPIC: Advanced Detection and Monitoring of Fires

A properly designed fire detection system must be able to identify, in a matter of seconds, a fire event which may occur only once in one hundred years, and the identification must lead to an action which is appropriate to the space being protected. Spaces of interest to the Building and Fire Research Laboratory include residential and

commercial structures, industrial facilities, transportation systems, and the urban/wildland interface. False alarms, maintenance problems, and incomplete or inaccurate information, which leads to an improper suppression response, are problems that plague many fire detection and/or suppression systems which are economically competitive. As the scientific basis for the identification of the characteristics of a pending fire become better established, research is required to determine how to apply advances in sensing temperature, heat flux, chemical species, particulate matter, and different portions of the electromagnetic and acoustic spectrum to the detection of a hazardous fire. New methods of signal processing and decision-making, based upon the most effective use of available knowledge, and the development of systems which adapt to changes to the environment being protected, are of particular interest. Proposals for incremental advances to existing fire detection technologies are not solicited. Refer to related descriptions in annual summaries of BFRL research.

8.13.12T SUBTOPIC: Advanced Fire Suppression and Novel Suppression Concepts

Fire protection of facilities requires suppressants that will not harm the environment nor cause excessive collateral damage to a structure or its contents. The need for alternatives which have low toxicity constrains one's choice of chemicals even more, suggesting that improved means for storage and delivery of less effective (but inherently safe) materials need to be addressed. Proposals are solicited which will improve any aspect of automatic fire suppression systems, such as more efficient storage of the agent, timely and precise delivery to the space being protected, enhanced interaction of the agent with the fire, and minimal negative interaction with the surroundings. Means to evaluate novel concepts at a reduced-scale which reliably predict full-scale operation should be addressed in the proposal. Inert gas systems and fine water sprays have little detrimental environmental impact. Methods to enhance their effectiveness as fire fighting agents and overcome their deficiencies (large quantity requirements and possible asphyxiation for inert gases, and significant collateral damage for water sprays) are legitimate topics. Other currently proposed halocarbon substitutes for halons are saddled with known or potential negative impacts on stratospheric ozone depletion or global warming, and it is unlikely that new compounds from this family will have both short atmospheric lifetimes and zero ODP. Approaches to more precisely predict the chemistry of alternative compounds in the atmosphere and to hasten their conversion to the most environmentally-friendly end-state are also sought. Refer to related descriptions in annual summaries of BFRL research.

8.13.13T SUBTOPIC: High Heat Flux Gauges and Calibrators

More precise measurement of heat flux in harsh, high temperature environments is required to understand and model the spread of unwanted fires. Proposals are solicited for novel transducers which can measure (and distinguish between) radiative and convective heat fluxes at levels up to 100 kW/m^2. Operational requirements include time response greater than 10 Hz, output linearity (within ± 5%) from 0.5 to 50 kW/m^2, flat spectral response in the visible and near infrared, size less than 4 cm^2, operating temperatures up to 300 °C, and resistance to condensation or particulate build-up. Proposals for methods or fixtures to calibrate heat flux gauges (traditional as well as new designs) in convective environments up to 50 kW/m^2 are also invited. Refer to the proceedings of a workshop on high heat flux calibration held at NIST in January 1995.

8.13.14T SUBTOPIC: Toxic Environmental Monitor for Fire Fighter and Research Use

The fire service experiences about 20 fire deaths each year. Some of these deaths are caused by the firefighter assuming incorrectly that the local atmosphere is sufficiently viable that escape will be possible even in the event of depletion of the self-contained breathing apparatus (SCBA) air supply which is normally employed. The primary toxic gases generated by fires are carbon monoxide (CO) and carbon dioxide (CO_2). Depletion of oxygen (O_2) leads to unconsciousness as well. A monitor is needed for measuring CO, CO_2, and O_2 levels simultaneously and providing a readable output to the firefighter's SCBA face shield. The monitor should also include a microcomputer that uses an algorithm to provide a conservative estimate of the time a typical person would be able to remain conscious in such an environment. The research use of the monitor would be for fire testing in which spatial resolution of gas concentrations is desired. For low temperature environments, the monitor could be placed at the site of interest, while for high temperature environments, the monitor would be exposed to extracted gases at a distance. The first generation monitor must have compact and lightweight sensors that together weigh less than 0.5 kg and have potential for further miniaturization. Control of the prototype system can be by microcomputer. The size of the system without the microcomputer must fit within a 100 cm^3 volume. It is expected that the microcomputer would eventually be replaced by a dedicated chip. The apparatus must be capable of withstanding a 100°C environment for 20 minutes. The accuracy of the CO and CO_2 sensors must be within 10% of their nominal readings, while the O_2 sensor must be within 5%. The system must be able to refresh visual and analog outputs at least once every 5 seconds. The ultimate cost of the components

must be below $1000. NIST welcomes proposals which will result in the development of a safety and measurement apparatus for the fire service and research communities.

8.13.15T SUBTOPIC: Temperature Measurements During Water Sprinkler Extinguishment of Fires

The development of models for describing the extinguishment of fires by water sprinklers is a current research priority of the Building and Fire Research Laboratory (BFRL). An important parameter to be used for validation of such models is the gas temperature field in the region influenced by both the sprinkler and the fire. Such measurements are particularly difficult due to the presence of both heated fire gases and water droplets. Innovative proposals are solicited by BFRL for a temperature sensor which is capable of measuring local gas-phase temperatures (room temperature to 500^{o} K) with a minimum sampling rate of 100 Hz during sprinkler-extinguishment of fires. Important considerations include high spatial resolution, ease of use in fire test, robustness, ability for automated data acquisition, and reasonable cost.

8.13.16T SUBTOPIC: Advanced Temperature Probe for Fire Testing

As the computational methods used to model fire scenarios become more sophisticated, there is a pressing need to improve the temporal and spatial resolution and reduce the uncertainty of temperature measurements used for validation. Presently used thermocouple methods are plagued by uncertainties. Temperature measurements are difficult in fires because of thermal radiation incident on the thermocouple from the fire (if the local gas is cooler than the surroundings), radiation losses from the thermocouple to the surroundings (if the local gas is hotter than the surroundings), soot accumulation on the thermocouple, and non-uniform heat transfer from the gas to the thermocouple due to recirculation and turbulence. The temporal response of thermocouples is limited by the thermal inertia of the bead, and time constants are often difficult to estimate. In addition, the metal structures on which thermocouples are mounted act as heat sinks and disturb the local flow. Proposals are solicited for innovative gas temperature measurement techniques for use in and around fires which are more accurate and precise and possess better spatial and temporal resolution than thermocouples. New methods should be able to measure local gas temperatures between 300 and 1500 K in an environment characterized by large temperature gradients, spatially and temporally nonuniform radiation fields, soot, and turbulence. New sensors should be rugged, long-lasting, and inexpensive. Rapid temporal response on the order of 1 ms and spatial resolution of less than 1 mm are desired to resolve local turbulence scales in fires. A technique capable of performing planar temperature measurements while satisfying the above listed constraints is desirable for validation of computer simulations. The temperature technique should minimize disturbance to the fire flow field, and should possess excellent and easily

calculable precision and accuracy. Only novel and innovative temperature probes will be considered.

8.13.17T SUBTOPIC: Rapid Time Response Heat Release Rate Sensor for Fire Testing

The release of fire-fighting agents and subsequent extinguishment of accidental fires takes place in a time period as short as 30 milliseconds. Few details are known about suppression under these conditions, because few instruments are capable of responding rapidly enough to resolve the behavior of the fire. One measurement which is necessary for studying suppression is the temporally resolved heat release rate of the fuel. The heat release rate is not necessarily equal to the mass loss rate of fuel; all of the fuel which evaporates does not necessarily burn. The heat release rate is the energy per unit time released by the fuel as it reacts with oxygen. Proposals are

References:

Nyden, M.R., G.P. Forney, and J.E. Brown. 1992. Molecular Modeling of Polymer Flammability: Application to the Design of Flame-Resistant Polyethylene. Macromolecules, **25**, 1658.

Nyden, M.R., T.R. Coley, and S. Mumby. 1997. Applications of Molecular Dynamics to the Study of Thermal Degradation in Aromatic Polymers. I. Polystyrene, *Polym. Eng. Sci.*, in press.

8.14 NIST TOPIC: INFORMATION TECHNOLOGY

8.14.1T SUBTOPIC: Extending RBAC to Include Work flow Properties

Work flow technology is the means by which business processes are automated and controlled. It has long been observed that RBAC concepts seem to complement and to some extent support work flow concepts. RBAC is a technology that allows for the specification and enforcement of a variety of protection policies which can be tailored on an enterprise-by-enterprise basis. The policies enforced in a particular system are the net result of the precise configuration of the various components of RBAC. It is felt that RBAC components can support or can be extended to support the specification of a business process in the context of a work flow. A Business Process is a set of one or more linked procedures or activities which collectively realize a business objective or policy goal, normally within the context of an organizational structure defining functional roles and role relationships. A process definition generally consists of many process activities which are logically related in terms of their contribution to the overall realization of the business process. These notions seem to map well to the RBAC framework that provides administrators with the capability to regulate who can perform what actions, when, from where, in what order, and in some cases under what relational circumstances.

NIST seeks research and experimental implementation to:

(1) Explore existing work flow approaches and standards to determine the degree in which RBAC models currently complement and support work flow concepts.

(2) Develop an extended RBAC model to include work flow concepts, whereby the extended model can be used to directly provide a means by which a work flow management system can ensure that the activities which make up a work flow are carried out in the correct sequence as prescribed by a predefined or ad hoc business process.

(3) Develop a prototype implementation exhibiting the properties of the extended model and a demonstration that shows the applicability of the model to real world business applications.

8.14.2T SUBTOPIC: Secure Programming Development Tools

New operational security vulnerabilities are continuously being discovered, exploited, reported, and catalogued. Vendors normally release software patches for these vulnerabilities once they are reported, while others release security scanning tools to detect them. Several forums and organizations are dedicated to tracking, analyzing, and reporting new vulnerabilities. The existence of these products and activities underscores the need for design strategies and supporting automated design and development tools to prevent security vulnerabilities from being introduced into products during both the design and development phase of the product.

The goal of this initiative is to develop tools that will enforce secure software design and development methodologies. The Secure Programming Development Tools envisioned for this effort should help developers design security into their products from the concept inception, and not as an afterthought. These tools should detect weaknesses in software engineering practices that lead to security problems, and help developers identify suspect code before the products are released for commercial use. Additionally, such tools, which also detect in legacy or existing code vulnerabilities, flaws, and/or poor software engineering practices that lead to tangible security weaknesses, are also highly desirable.

8.14.3T SUBTOPIC: Natural Language Interface to 3-D Character Animations

The use of animated human or human-like characters to supplement voice and text communication has long been recognized as a means of improving the motivational response to and/or clarity of multimedia presentations. When media presentations are prepared off-line, it is possible to develop predetermined 2-D character animations that convey specific meanings. This method does not work, however, when the character must interact to user responses with a shorter duration between events than the length of the animations, or when the character must be viewed interactively from multiple viewpoints. In these cases, a real-time 3-D representation of the character is required. Such 3-D characters have been used in multi-user web-based environments enabled by the emerging Virtual Reality Modeling Language (VRML). However, the expressions and/or gestures of these "avatars" have lacked visual realism and have been directly controlled as a response to a user selection from a small set of pre-defined actions. In

addition, control of human simulations which follows the Humanoid Animation Working Group (HANIM) of the VRML consortium is desired to improve portability and interoperability of systems. What is needed is a character that responds with enhanced realism to user or simulation initiated events.

8.14.4T SUBTOPIC: Improved Noise Robustness and Speech Detection for Large Vocabulary Continuous Speech Recognition (CSR) Technology

Current state-of-the-art CSR systems experience degradation of performance in the presence of background noise, especially when using other than head-mounted microphones. Current systems also cannot reliably discriminate between background noise and speech in background noise. Improved technology is needed to improve noise robustness for both continuous (stationary) and impulsive noise, and to discriminate between speech and noise. Ideally, the improved technology would permit reliable use of CSR technology with low-cost, remotely positioned microphones, and eliminate reliance on the use of push-to-talk microphones. This technology should also be valuable in automatic transcription and indexing of radio and TV broadcast materials, especially those portions of the broadcasts originating in other than broadcast studios.

8.14.5T SUBTOPIC: Ipv6/Ipsec

IP security is an emerging Internet technology that is currently under development, starting to be deployed, and will have a major impact on the Internet of the future. IP security involves the addition of IP-level headers that can provide authentication, integrity, and confidentiality to Internet traffic, along with protocols to handle the negotiation and management of the keys that will be used to protect this traffic. (For further information see: http://www.ietf.org/html.charters/ipsec-charter.html.) The IETF (Internet Engineering Task Force) documents that define these protocols are concerned with the formats of the packets that travel across the Internet, those packets that negotiate the key establishment, and those that carry the authenticated and/or encrypted messages.

These documents do not deal with a critical related issue: how can a system administrator or user enable these capabilities, specifying and controlling the system's security policy? Two interfaces are needed to accomplish this: an application-level interface that can be used by system administrators and users, and an API that can be called by application programs. It would be useful to design such an interface and then implement and test it. The interface should be compatible with and run under both the current Internet technology (IPv4) and the future Internet technology (IPv6). (For

further information, see: http://www.ietf.org/html.charters/ipngwg-charter.html, or http://playground.sun.com/pub/ipng/html). It should also run on a wide variety of computers and operating systems.

8.14.6T SUBTOPIC: Automated Network Security Administration and Configuration Tools

As the rate at which new products are being introduced into the market continues to increase, so does the complexity of securely administering distributed networks of personal computers, workstations, firewalls, web servers, and routers. Moreover, as new hardware, new software applications, vendor patches and upgrades, and network connections are continuously added to an organization's network, it is difficult to determine if the system is in a safe-state, and if the organization's security policy is being properly implemented and enforced. System administrators would benefit greatly from an Automated Network Security Administration and Configuration Tool that helps them securely configure and maintain distributed systems. These tools could, for example, include network resource discovery routines, track the installation of vendor patches, identify security vulnerabilities, and analyze the organization's security policy to ensure that it is being properly implemented. The goal of this effort is to develop a method for automatically configuring and maintaining the secure state of an organization's network system and a set of support tools that embody the method.